N.H.

9 geology

THE

QUARTERLY JOURNAL

OF THE

GEOLOGICAL SOCIETY OF LONDON.

EDITED BY

THE PERMANENT SECRETARY OF THE GEOLOGICAL SOCIETY.

Quod si cui mortalium cordi et curæ sit non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant. —*Novum Organum, Præfatio.*

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MCMXXI.

List

OF THE

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OF THE

GEOLOGICAL SOCIETY OF LONDON.

Elected February 20th, 1920.

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Prof. W. W. Watts.

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Dates of Issue of the Quarterly Journal for 1920.

No. 301—October 30th, 1920.

No. 302—November 30th, 1920.

No. 303—January 17th, 1921.

No. 304—March 9th, 1921.

PROCESS-BLOCKS AND OTHER ILLUSTRATIVE FIGURES

BESIDES THOSE IN THE PLATES.

PROCEEDINGS

OF THE

GEOLOGICAL SOCIETY OF LONDON.

SESSION 1919-20.

November 5th, 1919.

Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The List of Donations to the Library was read.

The Names of certain Fellows who are in Arrears with their Annual Contributions were read out for the second time, in accordance with the Bye-Laws, Sect. VI, Art. 5.

The President then made the following announcement:—

'The Council regret to inform the Fellows that Mr. C. P. Chatwin, who had been Librarian of the Society since May 1913, tendered his resignation on June 25th last, and in the course of October left to take up his new duties as Lecturer in Palæontology at the University of Liverpool. The regret of the Council at his resignation will be shared by all the Fellows who have experienced Mr. Chatwin's helpfulness. During the War, great demands were made on the resources of the Library by various Government Departments; and Mr. Chatwin responded ably to these demands, besides, in the enforced absence on war service of other members of the staff, taking a large part in the conduct of the Society's current business.

'In seeking to fill the post left vacant by Mr. Chatwin's resignation, the Council have fortunately been able to secure the services of Capt. Arthur Greig, who had entered the Society's service in 1908, joined the army in 1914, and remained in the service until he was demobilized in September this year. On receiving his application for the Librarianship, the Officers, taking into consideration his long experience of the Society's work and the admirable manner in which he had always fulfilled his duties, had no hesitation in provisionally appointing him to the post, and they have recommended the confirmation of his appointment by the Council, and the sanction thereof by the Fellows.'

A Lecture was then delivered by HUGH HAMSHAW THOMAS, M.A., F.G.S., 'On some Features in the Topography and Geological History of Palestine,' illustrated by aeroplane photographs taken during the War.

The Lecturer observed that a perfectly new method of illustrating and investigating some branches of physical geology is afforded by aeroplane photography. It seems first to illustrate in a very striking and convincing form many geological phenomena, such as the structure of a volcano or the land-forms resulting from erosion, and may be of value in the teaching of the science. In the second place it may, in certain circumstances, become a valuable means of research, especially in connexion with river-development or denudation in a region which is somewhat inaccessible, or where the surface of the ground is very complicated and the main features are obscured by a mass of less important detail. The lecture dealt principally with the illustration of the physical features of Palestine, and owed its origin to the systematic photographic survey made over Central Palestine during the War. The photographs were originally taken for the purpose of constructing detailed maps, and the examples shown had been selected from a large mass of similar material which still exists in the form of negatives, and these may eventually become available in this country for further study and research. The demarcation of the coastal plain from the foot-hills of the upland country is often well shown by oblique air-photographs, and the weathering-out of the flat alluvial ground by the winter rains to give characteristic wadis is clearly seen. In the central hill-country the terraced hills show the relation of the scenery to the underlying rock, but their general sculpture is regarded as belonging to a former period of great precipitation. In arid country, where the underlying rock is laid bare, the aeroplane camera often shows the general geological structure of the district.

The lacustrine deposits of the Jordan Valley and their weathering was shown, and also the form of the drainage-channels running down into the main valley. The depression of the Dead Sea with reference to the surrounding country has resulted in the formation of cañons in many places. Some evidences of faulting at different periods can be distinguished.

The Jordan at present forms an interesting study in river-development, and many of its main features were demonstrated. The relation of the Jordan to the Orontes has been considered, and an aeroplane photographic survey of the country between the two rivers indicates that the Jordan probably originated in Northern Syria in earlier times. The Syrian portion of the stream has been captured by the younger Orontes, and this has had a very important effect on the whole topography of the Jordan Valley.

A further study of the aeroplane photographs already taken, and of the maps made from them, may throw much new light on the

questions of climatic changes and of topographical changes due to faulting in Palestine.

A vote of thanks was unanimously accorded to Mr. Thomas for his lecture.

November 19th, 1919.

Mr. G. W. Lamplugh, F.R.S., President,
in the Chair.

Wilfred Stanley Lewis, B.Sc., Kenwyn, Marlborough Road, Falmouth, was elected a Fellow of the Society.

The List of Donations to the Library was read.

The following communication was read:—

'The Pleistocene Deposits around Cambridge.' By Prof. John Edward Marr, Sc.D., F.R.S., V.P.G.S.[1]

Implements, worked flints, and fossil mollusca were exhibited by Prof. J. E. Marr, in illustration of his paper.

December 3rd, 1919.

Mr. G. W. Lamplugh, F.R.S., President; and, afterwards,
Mr. R. D. Oldham, F.R.S., Vice-President, in the Chair.

Harold Cuthbert Brooksbank Brown, 7 Libertus Road, Cheltenham; John Morrow Campbell, c/o Steel Brothers & Co., Ltd., Rangoon (Burma); William Francis Henry Creber, M.Inst.C.E., Tanjore, St. Germans (Cornwall); Capt. Alfred Edward Day, M.C., B.Sc., c/o the Indo-Burma Petroleum Company, Rangoon (Burma); Frederick William Dennis, Holly Cottage, Ricardo Street, Longton (Staffordshire); Mary Kingdon Heslop, M.Sc., Demonstrator in Mineralogy at Armstrong College, 20 Framlington Place, Newcastle-upon-Tyne; Ernest Wilfrid Jackson, F.C.S., F.I.C., Godrevy, Saltburn-by-the-Sea (Yorkshire); David Morgan Jenkins, M.Inst.C.E., Frondeg, Neath (Glamorgan); George Edward Jennings, Ashleigh, Ashleigh Road, Leicester; Hester Julian (*née* Pengelly), Redholme, Braddon's Hill Road, Torquay; Yu Yon Lee, A.R.C.S., Royal School of Mines, South Kensington, S.W.7; James Lomax, Oakenbottom, Tongue, Bolton (Lancashire);

[1] Published in Q. J. G. S. vol. lxxv (1919–20) pp. 204–42.

William Archibald Macfadyen, B.A., St. John's College, Cambridge; Adam Morgan, B.Sc., City Engineer's Office, Guildhall, Londonderry; Roderick Charles Murchison, Hargrave Hall, Kimbolton (Huntingdonshire); Frank Russell, Auldam House, Worksop (Nottinghamshire); Harold Montague Sale, B.A., Geologist to the Burma Oil Company, Arden Hill, Atherstone (Warwickshire); Herbert Victor Searle, M.Sc., Oamaru (New Zealand); William George St. John Shannon, Beverley Lodge, Torquay; Capt. Frederick Thomas Smedley, R.E., Bradmore, Marion Road, Mill Hill, N.W. 7; Edmondson Spencer, B.Sc., 30 Lenches, Colne (Lancashire); Percy Albert Wagner, D.Eng., B.Sc., Geological Survey of South Africa, P.O. Box 401, Pretoria (Transvaal); and Dorothy Margaret Woodhead, B.A., Lynton, 14 Tower Road, Dartford (Kent), were elected Fellows of the Society.

The List of Donations to the Library was read.

Mr. S. Hazzledine Warren, F.G.S., exhibited and commented on a collection of Neolithic Implements from Graig-lwyd, near Penmaenmawr (North Wales).

Prof. W. W. Watts, Sc.D., F.R.S., exhibited and described a new Geological Map of Western Australia, prepared by the Geological Survey of Western Australia, under the direction of Dr. A. Gibb Maitland, F.G.S.

Mr. C. N. Harris, Chairman of the Western Australia Committee of the Institution of Mining & Metallurgy and of the Committee of Repatriation, exhibited a Collection of Minerals from Western Australia which he had presented to the Imperial College of Science & Technology, and commented chiefly on those of economic interest.

The President (Mr. G. W. Lamplugh) summarized briefly the phenomena presented by the Dry-Lake Areas of Western Australia, illustrating his remarks with lantern-slides lent by the Royal Geographical Society.

He also exhibited specimens from Permo-Carboniferous Glacial Deposits of the Irwin-River district (Western Australia).

December 17th, 1919.

Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

The List of Donations to the Library was read.

The SECRETARY read the following communication, received from the Under Secretary of State for the Colonies :—

Headquarters, Rabaul, May 20th, 1919.

Memorandum addressed to the Secretary for Defence, Melbourne.

'I have to report a severe earthquake shock, experienced in Rabaul on the morning of the 7th inst. As nearly as can be ascertained, the first tremor occurred at 5.40 A.M. It took the form of a preliminary shake, and was followed by a long shock, or succession of shocks. The ground rocked in a most alarming manner, trees swayed backwards and forwards, cracks appeared in the surface of the earth, and much damage was caused to property.

'Of course, ordinary earth-tremors are of such common occurrence here that they do not even cause comment. But, despite the exceptionally wet season, there had been a marked absence of "gourryas" (as the natives call these shocks) for several weeks. Whether the shock in question was the result of the stored-up energy thereby conserved, or not, it is a fact that it more than made up for our previous immunity. The morning of the 7th was marked by an extraordinarily vivid sunrise, and many natives affirmed that the vivid colours in the sky foretold the earthquake. None of them, however, appear to have actually prophesied it before the event. Reveillé had blown at 5.30 A.M., and the men of the garrison were preparing to go on early morning parade at 6 o'clock when the shock came. The wooden bungalows rocked to and fro, rifles were forcibly thrown from the racks, and a few who were snatching some minutes' extra sleep were pitched off their stretchers, which were overturned on top of them.

'The shock was felt most severely on Namanula Hill, outside Rabaul, upon the summit of which Government House is built. The two portions of the house, separated by a wide gangway, rocked in opposite directions, until persons on the verandahs had all the sensations of being tossed about in a gale at sea. The furniture in all the bungalows went crashing hither and thither, and vast quantities of glass and crockery were smashed. When the earthquake subsided, most of the houses built on the hill presented an extraordinary appearance, the supports being tilted at all angles. Heavy 1000-gallon tanks were rolled over like toys, and our Government Printing Office was completely wrecked.

'Naturally, the roads suffered considerably. The road from Namanula to Rabaul is cut out of the hillside, and winds through steep cuttings. In many places the hillside collapsed, completely filling these cuttings, and in other places portions of the road itself slipped down the gully. One of my Staff Officers was riding down to Rabaul, and was half-way through a cutting, when a rumbling noise, which he described as reminiscent of an express train approaching, startled his horse. Before he had time to realize what had happened, the ground started rocking under his horse; the trees far above him commenced swaying, and 30 yards in front of him, the side of the cutting broke away and filled the road to the depth of about 15 feet. The officer hastily turned his trembling horse to ride back, when he found that the cutting was collapsing at the other end as well.

'These earthquakes appear to be closely associated with the volcanic belt in this region, and the earthquake on the 7th was followed by great activity in the sulphur-springs at the foot of Mount Mother, the green fumes spreading over the sea to a height of about 100 feet.

'A tidal wave of some magnitude was experienced at Kokopo, where the s.s. *Nusa* was compelled to put hastily to sea, so as not to be swept on to the beach. The wave took up and tossed a large whaleboat upon the wharf, and then receded so far as to leave the wharf entirely out of the water for the time being. Even at Rabaul, the wave was of such proportions as to leave thousands of fishes stranded above the high tide-mark. Despite extensive damage done to property, it is remarkable that not a single casualty has been

reported. This is attributable partly to the fact that the earthquake occurred before most people were about, and partly to the fact that buildings here are built on high piles, with the primary idea of withstanding shocks.

'It is noteworthy that since the earthquake occurred, about a fortnight ago, scarcely a day has passed without several minor tremors.

'GEORGE J. JOHNSON, Brigadier-General, Administrator.'

The SECRETARY then read the following communication received from REGINALD RAOUL LEMPRIERE, M.A., F.G.S., concerning a raised beach at South Hill, St. Helier (Jersey), of which a description was originally published by the late Dr. Andrew Dunlop, in Q. J. G. S. vol. xlix (1893) pp. 523–25:—

'In the 36th Bulletin of the Société Jersiaise (1911), Dr. Dunlop dealt with the objection made in the discussion, which followed the reading of his paper published in the Q. J. G. S., that no shells or other marine organisms had been found in the raised beaches, and this view was subsequently supported by Geinitz. "But this objection is of little value, for in many, if not in most, of our present shingle-beaches no shells or marine organisms are to be met with, as they are ground to pieces and destroyed by the comparatively large pebbles of hard heavy rock. The only alternative, also, to a marine origin would be a fluviatile one; but it is not easy to see how a river could have laid down the beds of gravel on the southern, northern, eastern, and western shores and slopes of the island, and filled up caves on the north coast. Further, the large, smooth, well-rounded pebbles of hard granite and diorite look more like the work of the sea than of a river; and, in fact, it may be safely concluded that there was a marine submergence. As the raised beaches contain no organic remains (at least none so far have been found), it is difficult to give them an exact geological date; indeed, we cannot be sure that they all belong to the same part of the Quaternary period, though this seems likely. They are probably of early Pleistocene age and contemporary with some of the raised beaches of Britanny, of Northern France, and of Southern England."

'In company with Dr. Dunlop I have formerly viewed from a distance the line of sea-pebbles exposed on the face of the high cliff east of the South Hill battery; but no attempt to make a close examination was possible, and it could not easily be cut into on the cliff-face. Its westward extent was quite unknown. On October 30th, 1918, by the invitation of Major T. E. Naish, R.E., who had notified me as soon as he had struck the beach in the course of the military works undertaken, I visited the spot in company with Mr. Émile Guiton, a member of the geological section of the Société Jersiaise, and took note of the great mass of seaworn granite-pebbles and boulders already exposed. The beach from the face of the cliff going westward forms a tongue, and the excavations had struck across a spot nearing the tip of this tongue. With the exception of a few small stones of diorite and diabase, the sea-worn rounded shingle was perfectly uniform in character, consisting of a fine-grained granite, brownish pink in colour, and having a greater excess of hornblende and less quartz than the granite of the northern coast of Jersey. In fact, the rock may be described as closely approaching to a syenite-granite. As usual, the smaller pebbles were on the top, and increased in size until the floor of the gully was struck. I again visited the excavations in company with members of the Société Jersiaise on December 31st, 1918, and on January 11th & 22nd, 1919. On the two last-named dates we were permitted to take photographs of the sea-beach and of the gully in which the deposit lay (or rather had lain), for the gully, so far as opened out, had been cleaned in order to give a full inspection. The walls of the gully were polished exceedingly smooth, and exhibited superficial fissures. Many similar gullies are to be seen equally worn, at or below high-water mark, around the coast of the island. The total

mass of rounded pebbles and boulders exposed was very considerable, and a much greater quantity remains untouched between the section cut into and the face of the cliff as one goes south-eastwards, a distance of some 35 feet. The beach itself, taken in the gully, is 127 feet 9 inches above mean sea-level. No shells were found, although carefully looked for, and it is not likely that they could have survived the lengthy grinding action of the sea, when this large mass of granite-fragments was rolled up and down in the gully, and to such an extent as to wear the walls to a polished surface. There are some remains of a sea-beach on the northern coast of Jersey, at a level of 155 feet above the sea; but, as regards mass and complete evidence of that mass lying in a finely polished rock-gully, the South Hill high-level sea-beach takes the first place in point of interest among the sea-beaches that have so far been noted and examined in Jersey.'

In the absence of the Author, the following paper was read by Mr. R. D. OLDHAM, F.R.S., V.P.G.S.:—

'A Rift-Valley in Western Persia.' By Prof. S. James Shand, D.Sc., F.G.S.[1]

A cast of an Italian Renaissance Medal of Leonello Pio, Count of Carpi, dating from about A.D. 1500, and bearing on its reverse a design representing a volcano in eruption (Vesuvius), was exhibited by Mr. C. Davies Sherborn, F.G.S.[2]

January 7th, 1920.

Mr. G. W. LAMPLUGH, F.R.S., President,
in the Chair.

The List of Donations to the Library was read.

The following Fellows of the Society, nominated by the Council, were elected Auditors of the Society's Accounts for the preceding year:—S. HAZZLEDINE WARREN and BERNARD SMITH, M.A.

The following communications were read:—

1. 'On *Syringothyris* Winchell, and certain Carboniferous Brachiopoda referred to *Spiriferina* D'Orbigny. By Frederick John North, B.Sc., F.G.S.

2. 'Jurassic Chronology: –I—Lias. Supplement 1, West England Strata.' By S. S. Buckman, F.G.S. (Read, in the absence of the Author, by Dr. W. D. Lang, M.A., F.G.S.)

Specimens of fossil brachiopoda and lantern-slides were exhibited by Mr. F. J. North, in illustration of his paper.

[1] Published in Q. J. G. S. vol. lxxv (1919–20) pp. 245–50.
[2] See Geol. Mag. 1919, p. 195.

January 21st, 1920.

Mr. G. W. Lamplugh, F.R.S., President,
in the Chair.

David Buttle, M.I.Mech.E., Iquique (Chile); Charles Panzetta Chatwin, University Lecturer in Palæontology, Geological Department of the University of Liverpool; James Davies, 11 Newport Road, Tre Thomas, Bedwas, Cardiff; Walter Gilbert Langford, M.Sc., Vailala Oilfields (Papua); Edward Merrick, M.Sc., 66 Rothbury Terrace, Newcastle-upon-Tyne; Florence Annie Pitts, Bankside, Cliftonville, Dorking (Surrey); Pierre Pruvost, D.-ès-Sc., Maître de Conférences de Géologie at the University of Lille, 159 Rue Brûle-Maison, Lille (France); Mrs. Eleanor Mary Reid, B.Sc., F.L.S., Pinewood, Milford-on-Sea (Hampshire); Howard James Walker, M.I.M.E., Mining Engineer, 8 Park Avenue, Southport (Lancashire); and Alfred Kingsley Wells, Assistant Lecturer & Demonstrator in Geology at King's College (University of London), Holmsdale, Buckhurst Hill (Essex), were elected Fellows of the Society.

The List of Donations to the Library was read.

Mr. Richard Dixon Oldham, F.R.S., V.P.G.S., gave a demonstration on a Model to Illustrate the Hypothesis of a somewhat Rigid Crust resting on a somewhat Yielding Substratum, as applied to the Problem of the Origin of Mountain-Ranges.

He remarked that geodetic measurements in the Himalayas, the Pamirs, and the Andes show that in each case there are systematic departures from equilibrium, in the form of parallel zones in which the surface-level stands alternately above and below the level of equilibrium, the differences being very considerable, and amounting to the equivalent of somewhat over 2000 feet thickness of rock of average density. These zones run parallel to the direction of the axis of greatest elevation of the range, and are explicable by an hypothesis that the elevation of the ranges was due to direct uplift produced by changes in volume of the material underlying the crust, if this material be supposed to possess a certain limited amount of compressibility or plasticity and the crust to have a certain amount of rigidity, which would offer resistance to an exact adjustment of the uplift of the surface to the varying amount of uplifting force developed in the material below the crust.

The model is designed to visualize the consequences of such an hypothesis. It consists of two strips of spring steel, supported at regular intervals by connecting links to a series of blocks capable of vertical movement. For one strip these links are of fixed length, representing a condition in which surface-elevation will be exactly equivalent to the magnitude of the uplifting force. For

the other the links have a limited possibility of variation in length, representing a condition where the rigidity of the crust is given a certain possibility of influence on the resulting elevation of the surface. On giving differences in height to the elevating blocks, to represent the varying amount of uplifting force supposed to exist under the mountain-range, it is found that the two strips do not run at the same level, but the second runs alternately higher and lower than the first, just as geodetic measurements have shown is the case in the great ranges of mountains. The model is of no value as evidence in favour of the hypothesis which it was designed to illustrate, but is regarded as of some interest in visualizing the consequences of an hypothesis which seems worthy of closer investigation than it has yet received.

February 4th, 1920.

Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

Francis Alleyne Marr, D.S.O., Geologist to the Burma Oil Company, c/o Messrs. Scott & Co., Rangoon (Burma); and the Rev. Benjamin Oriel, B.A., B.Sc., 26 Parkside, Eltham, S.E. 9, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communication was read:—

'Geological Sections through the Andes of Peru and Bolivia: II—From the Port of Mollendo to the Inambari River.' By James Archibald Douglas, M.A., B.Sc., F.G.S.

Rock-specimens and lantern-slides were exhibited by Mr. J. A. Douglas, in illustration of his paper.

Flints showing artificially-made bulbs of percussion were exhibited by Dr. John Switzer Owens, F.G.S.

February 20th, 1920.

George William Lamplugh, F.R.S., President, in the Chair.

Report of the Council for 1919.

During the year under review, 81 new Fellows were elected into the Society (49 more than in 1918). Of the Fellows elected in 1919, 64 paid their Admission Fees before the end of that year, and of the Fellows who had been elected in the previous year 7 paid their Admission Fees in 1919, making the total accession of new Fellows during the past year amount to 71 (39 more than in 1918).

Allowing for the loss of 56 Fellows (7 resigned, 32 deceased, and 17 removed), it will be seen that there is an increase of 15 in the number of Fellows (as compared with a decrease of 33 in 1918).

The total number of Fellows (including 3 Fellows reinstated) is, therefore, at present 1207, made up as follows:—Compounders 208 (5 less than in 1918); Contributing Fellows 986 (24 more than in 1918); and Non-Contributing Fellows 13 (1 less than in 1918).

Turning now to the Lists of Foreign Members and Foreign Correspondents, the Council announces with regret the loss during the past year of Dr. Paul Choffat and Dr. Francisco P. Moreno, Foreign Correspondents. These losses increase the number of vacancies in the List of Foreign Correspondents to twelve, while the vacancies in the List of Foreign Members amount to six.

With regard to the Income and Expenditure of the Society during 1919, the figures set forth in detail in the Balance-Sheet may be summarized as follows:—The actual Receipts (excluding the Balance of £107 17*s.* 6*d.* brought forward from the previous year, and also a grant of £100 made by the Royal Society) amounted to £3431 16*s.* 7*d.*, being £659 15*s.* 7*d.* more than the estimated Income. This is due to the fact that the sums received in respect of Admission Fees, Compositions, and Annual Contributions greatly exceeded the Estimates.

On the other hand, the Expenditure during the same year amounted to £3159 14*s.* 5*d.*, being £290 19*s.* 5*d.* more than the estimated Expenditure (this includes the sum of £109 18*s.* 5*d.* paid in respect of Vol. LXXV of the Journal), and the year closed with a Balance in hand of £376 13*s.* 8*d.*

The financial prosperity of the Society is, however, more apparent than real, as much expenditure remains to be incurred in respect of

arrears of publications and binding of books. As a step towards meeting these and other prospective increasing liabilities, the Council submitted to the Fellows, at a Special General Meeting, held on June 25th, 1919, alterations in the Bye-Laws raising the Annual Contribution in the case of all Fellows elected after November 1st of that year to Three Guineas, and raising the Composition Fee in the case of such Fellows to Fifty Guineas. The alterations were carried with one dissentient.

As regards the publications of the Society, the Council has to announce the completion of Vol. LXXIV of the Quarterly Journal (1918) and the commencement of Vol. LXXV (1919).

During the past year the Apartments of the Society have been used for General and for Council Meetings by the Institution of Mining Engineers, the Institution of Mining & Metallurgy, the Institution of Water Engineers, the Institution of Municipal & County Engineers, the Society of Engineers, the Mineralogical Society, the Palæontographical Society, the Ray Society, the Royal Anthropological Institute, the Royal Meteorological Society, and the South-Eastern Union of Scientific Societies.

Sir Aubrey Strahan and Prof. W. G. Fearnsides have continued to act during the year as our representatives on the Conjoint Board of Scientific Societies.

On March 26th, 1919, a Special General Meeting was held, at which the resolution of the Council affirming the desirability of admitting Women as Fellows of the Society was carried by 55 votes to 12. Fourteen have so far availed themselves of the opportunity thus afforded.

The suggestion of the Council to revert to the hour of 8 P.M. for the Ordinary Meetings was considered by the Fellows at the Special General Meeting held on June 25th, but the majority present decided to maintain the hour of meeting at 5.30 P.M.

No Award was made from the Daniel-Pidgeon Trust Fund in 1919, no candidate having been nominated.

The following Awards of Medals and Funds have been made:—

The Wollaston Medal is awarded to Prof. Gerard Jakob De Geer, in recognition of his researches concerning the 'mineral structure of the Earth,' more especially in connexion with the geology of Scandinavia and Spitsbergen.

The Murchison Medal, together with the sum of Ten Guineas from the Murchison Geological Fund, is awarded to Ethel Mary Shakespear, D.Sc., in recognition of the value of her palæontological researches on the Graptolitoidea and of her contributions to the stratigraphy of the Older Palæozoic rocks.

The Lyell Medal, together with the sum of Twenty-Five Pounds, is awarded to Mr. Edward Greenly, as a mark of appreciation of the value of the geological work carried out by him in the Island of Anglesey.

The Balance of the Proceeds of the Wollaston Donation Fund is awarded to Mr. William Bernard Robinson King, in recognition of the value of his geological activities at General Headquarters in

France during the years 1915–19, and as an incentive to further work.

The Balance of the Proceeds of the Murchison Geological Fund is awarded to Dr. David Woolacott, as an acknowledgment of the value of his contributions to the geology of the North-East of England, and in order to stimulate him to further work.

A Moiety of the Balance of the Proceeds of the Lyell Geological Fund is awarded to Dr. John Downie Falconer, in recognition of the value of his researches, both at home and abroad, but more particularly in connexion with the geology of Nigeria.

A Moiety of the Balance of the Proceeds of the Lyell Geological Fund is awarded to Mr. Ernest Sheppard Pinfold, in recognition of the value of his contributions to Indian stratigraphy, and to stimulate him to further research.

Report of the Library Committee for 1919.

The accessions to the Library during the past year have not differed greatly in amount from those of the three previous years. Exchange of publications has not yet been resumed with former enemy countries, and indeed only one institution so far (the Senckenbergische Gesellschaft of Frankfurt-on-the-Main) has requested a resumption of exchange.

In view of the continual growth of the Library, the question of the advisability of retaining and binding the numerous serial publications (such as the Journal of the Royal Society of Arts, the Chemical News, the Journal of the Chemical Society, etc.) which are not mainly geological in character, will inevitably come up for consideration. By partial or entire elimination of such serials, much needed space would be saved, and economies would be effected in binding. Comparatively little binding was done during the year 1919.

The resignation of Mr. C. P. Chatwin, who had faithfully served the Society as Librarian since 1913, took effect in October last, and he has been succeeded by Mr. Arthur Greig (lately Captain in the London Scottish Regiment), who before the War had been in the service of the Society for six years. Mr. Chatwin has undertaken to complete the preparation for the Press of No. 20 of the 'List of Geological Literature' (1913). The Committee wish gratefully to acknowledge a grant of £100 from the Royal Society towards the publication of that volume. The ways and means of continuing and bringing this bibliographical record up to date should receive immediate consideration by the Council.

The Donations received during the year number 12 Volumes of separately published Works, 199 Pamphlets, and 5 detached Parts of Works, also 120 Volumes and 203 detached Parts of Serial

Publications, 29 Volumes and 153 detached Parts of the publications of Geological Surveys and other public bodies, and 8 Volumes of Weekly Periodicals.

As was the case in 1918, only 2 sheets of Geological Maps have been received.

The total number of accessions by Donation amounts, therefore, to 161 Volumes, 199 Pamphlets, and 361 detached Parts.

Special attention may be drawn to the following works :—

'A Bibliography of Indian Geology & Physical Geography,' with an Annotated Index of Minerals of Economic Value, compiled by T. H. D. La Touche, & published by the order of the Government of India, 1918; 'La Face de la Terre (Das Antlitz der Erde),' translated by Prof. E. de Margerie, vol. iii, pt. 4 (end), and also Index of the whole work, 1918; S. G. Burrard's 'Investigations of Isostasy in Himalayan & Neighbouring Regions' (Professional Paper No. 17, Geological Survey of India), 1918; 'Shore Processes & Shore-Line Development,' by D. W. Johnson, 1919; Prof. H. F. Osborn's Memoir on the 'Equidæ of the Oligocene, Miocene, & Pliocene of North America—Iconographic Type-Revision,' published by the American Museum of Natural History, 1918; 'Fossil Plants,' by Prof. A. C. Seward, vol. iv, 1919; Prof. W. W. Watts's 'Handbook on the Geography of Shropshire,' 1919; 'Les Gîtes Minéraux,' by Stanislas Meunier, 1919; the 5th Edition of Mr. H. Woods's 'Palæontology—Invertebrate,' 1919; Mr. S. S. Buckman's 'Memoir on the Brachiopoda of the Namyan Beds, Northern Shan States, Burma,' published by the Geological Survey of India, 1917; 'The Geology of South Perak, North Selangor & the Dindings,' by J. B. Scrivenor & W. R. Jones, published by the Geological Department of the Federated Malay States, 1919; the Geological Survey's Special Reports on the Mineral Resources of Great Britain, dealing with the Hæmatites of West Cumberland, Lancashire, & the Lake District (vol. viii); and those of the Forest of Dean & South Wales (vol. x); Sundry Unbedded Ores of Durham, East Cumberland, & other Parts of England & Wales (vol. ix); and the District Memoir on the Geology of the Country around Lichfield, 1919.

The Donors during the preceding year included 92 Government Departments and other Public Bodies, 99 Societies and Editors of Periodicals, and 103 Personal Donors.

The Purchases included 11 Volumes and 10 detached Parts of Works, and 12 Volumes and 24 detached Parts of Works published serially.

The Expenditure incurred in connexion with the Library during 1919 was as follows :—

	£	s.	d.
Books and Periodicals	37	4	0
Binding	35	17	0
Catalogue Cards, etc.	0	4	6
Total	£73	5	6

Mr. C. Davies Sherborn reports that

'into the Card-Catalogue have now been sorted the slips and index-cards from the last-published volume of the Royal Society's Catalogue, which claims to contain the literature from 1883 to 1900, up to the letter M; also the slips of the List of Geological Literature for 1912. Editing of all these slips remains to be done.'

The appended Lists contain the Names of Government Departments, Public Bodies, Societies, Editors, and Personal Donors, from whom Donations to the Library have been received during the year under review:—

I. Government Departments and other Public Bodies.

Athens.—Observatoire National d'Athènes.
Australia, Government of the Commonwealth of. Melbourne.
Belgium.—Académie Royale des Sciences, Lettres, & Beaux-Arts. Brussels.
Bergens Museum. Bergen.
Birmingham, University of.
Boston.—American Academy of Arts & Sciences.
Bristol Museum & Art Gallery.
British Columbia.—Department of Mines. Victoria (B.C.).
British Guiana.—Department of Mines. Georgetown.
Bulawayo.—Rhodesian Museum.
California.—Academy of Sciences. San Francisco.
——, University of. Berkeley (Cal.).
Cambridge (Mass.).—Museum of Comparative Zoology in Harvard College.
Canada.—Department of Mines. Ottawa.
——, High Commissioner for. London.
Colorado.—Bureau of Mines. Denver.
Connecticut.—Geological & Natural History Survey. Hartford.
Córdoba (Argentine Republic).—Academía Nacional de Ciencias.
Denmark.—Geologiske Undersögelse. Copenhagen.
——. Kongelige Danske Videnskabernes Selskab. Copenhagen.
Dublin.—Royal Irish Academy.
Egypt.—Survey Department, Ministry of Finance. Cairo.
Federated Malay States.—Geological Department. Kuala Lumpur.
Gold Coast. Geological Survey. Accra.
Great Britain.—British Museum (Natural History). London.
——. Colonial Office. London.
——. Geological Survey. London.
——. Home Office. London.
——. Local Government Board. London.
Holland.—Rijksopsporing van Delfstoffen. The Hague.
Illinois State Geological Survey. Urbana (Ill.).
India.—Department of Mines.
——. Geological Survey. Calcutta.
Japan.—Earthquake-Investigation Committee. Tokyo.
——. Imperial Geological Survey. Tokyo.
Lausanne, University of.
London.—Imperial College of Science & Technology.
——. Imperial Institute.
——. Imperial Mineral Resources Bureau.
——. University College.
Madrid.—Real Academía de Ciencias Exactas, Físicas & Naturales.
——. Instituto Geológico de España.

Mexico.—Department of Mines. Mexico City.
——. Instituto Geológico. Mexico City.
Minnesota.—Geological Survey. Minneapolis.
Mysore.—Geological Department. Bangalore.
New Haven (Conn.).—Yale University.
New South Wales.—Department of Mines. Sydney
New York.—American Museum of Natural History.
New Zealand.—Department of Mines. Wellington.
——. Geological Survey. Wellington.
Norway.—Geologiske Undersökelse. Christiania.
Norwich.—Castle Museum.
Ontario.—Bureau of Mines. Toronto.
Paris.—Académie des Sciences.
——. Commission des 'Annales des Mines.'
——. Muséum d'Histoire Naturelle.
Philippine Is.—Department of the Interior: Bureau of Science. Manila.
Portugal.—Commissão do Serviço Geologico. Lisbon.
Quebec.—Department of Colonization, Mines, & Fisheries.
Queensland, Agent-General for. London.
——. Department of Mines. Brisbane.
——. Geological Survey. Brisbane.
Rio de Janeiro.—Museu Nacional.
Rome.—Reale Accademia dei Lincei.
Sendai (Japan).—Tohoku Imperial University.
South Africa, Union of.—Department of Mines. Pretoria.
South Australia, Agent-General for. London.
——. Department of Mines. Adelaide.
——. Geological Survey. Adelaide.
——. Royal Commission on Water-Supply. Adelaide.
Southern Rhodesia.—Geological Survey. Salisbury.
Stockholm.—Kongliga Svenska Vetenskapsakademi.
Sweden.—Sveriges Geologiska Undersökning. Stockholm.
Switzerland.—Geologische Kommission der Schweiz. Berne.
Tasmania.—Geological Survey. Hobart.
——. Minister of Mines. Hobart.
Tokyo.—College of Science (Imperial University).
Turin.—Reale Accademia delle Scienze.
United States.—Geological Survey. Washington (D.C.).
——. National Museum. Washington (D.C.).
Upsala, Royal University of.
Victoria (Australia), Agent-General for. London.
—— (——). Department of Mines. Melbourne.
—— (——). Geological Survey. Melbourne.
——. State Rivers & Water Commission. Melbourne.
Washington University. St. Louis (Mo.).
Washington (D.C.).—Smithsonian Institution.
——. Geophysical Laboratory.
Western Australia, Agent-General for. London.
——. Department of Mines. Perth.
——. Geological Survey. Perth.

II. Societies and Editors.

Adelaide.—Royal Society of South Australia.
Basel.—Naturforschende Gesellschaft.
Belfast.—Natural History Society.
Bergen.—'Naturen.'
Berne.—Naturforschende Gesellschaft.
Bombay.—Bombay Branch of the Royal Asiatic Society.
Bristol Naturalists' Society.
Brussels.—Société Belge de Géologie.
——. Société Royale Zoologique & Malacologique.
Caen. Société Linnéenne de Normandie.
Cambridge Philosophical Society.

Cape Town.—Royal Society of South Africa.
——. South African Association for the Advancement of Science.
Cardiff.—South Wales Institute of Engineers.
Chicago.—'Journal of Geology.'
Coimbra.—Academia Polytechnica do Porto.
Colombo.—Ceylon Branch of the Royal Asiatic Society.
Dorchester.—Dorset Natural History & Antiquarian Field-Club.
Dublin.—Royal Dublin Society.
Edinburgh.—Royal Scottish Geographical Society.
——. Royal Society.
Falmouth.—Royal Cornwall Polytechnic Society.
Fribourg.—Société Fribourgeoise des Sciences Naturelles.
Geneva.—Société Paléontologique Suisse.
——. Société de Physique & d'Histoire Naturelle.
Gloucester.—Cotteswold Naturalists' Field-Club.
Halifax (N.S.).—Nova Scotian Institute of Science.
Hamilton (Canada).—Scientific Association.
Hull.—Scientific & Field Naturalists' Club.
Johannesburg.—Geological Society of South Africa.
Lancaster (Pa.).—'Economic Geology.'
Lausanne.—Société Géologique Suisse.
——. Société Vaudoise des Sciences Naturelles.
Liége.—Société Géologique de Belgique.
——. Société Royale des Sciences.
Lisbon.—Academia das Sciencias. Coimbra.
Liverpool.—Literary & Philosophical Society.
London.—British Association for the Advancement of Science.
——. Chemical Society.
——. 'The Chemical News.'
——. 'The Colliery Guardian.'
——. 'The Geological Magazine.'
——. Geologists' Association.
——. Institution of Civil Engineers.
——. Institution of Mining Engineers.
——. Institution of Mining & Metallurgy.
——. Institution of Water Engineers.
——. Iron & Steel Institute.
——. Linnean Society.
——. 'The London, Edinburgh, & Dublin Philosophical Magazine.'
——. Mineralogical Society.
——. 'The Mining Magazine.'
——. 'The Naturalist.'
——. 'Nature.'
——. 'The Quarry.'
——. Royal Agricultural Society.
——. Royal Geographical Society.
——. Royal Institution.
——. Royal Meteorological Society.
——. Royal Microscopical Society.
——. Royal Photographic Society.
——. Royal Society.
——. Royal Society of Arts.
——. Society of Engineers.
——. 'Water.'
——. Zoological Society.
Manchester Geological & Mining Society.
——. Literary & Philosophical Society.
Melbourne (Victoria).—Australasian Institute of Mining Engineers.
——. Royal Society of Victoria.
——. 'The Victorian Naturalist.'
Mexico.—Sociedad Científica 'Antonio Alzate.'
Nancy.—Académie de Stanislas.
Newcastle-upon-Tyne.—North of England Institute of Mining & Mechanical Engineers.
New Haven (Conn.).—Academy of Arts & Sciences.
——. 'The American Journal of Science.'
New York.—American Institute of Mining Engineers.

Northampton.—Northamptonshire Natural History Society.
Ottawa.—Royal Society of Canada.
Paris.—Société Française de Minéralogie.
——. Société Géologique de France.
Perth.—Perthshire Society of Natural Sciences.
Philadelphia.—Academy of Natural Sciences.
——. American Philosophical Society.
Pisa.—Società Toscana di Scienze Naturali.
Plymouth.—Devonshire Association for the Advancement of Science.
Rochester (N.Y.).—Geological Society of America.
Rome.—Società Geologica Italiana.
——. Comitato Glaciologico Italiano.
Rugby School Natural History Society.
Santiago de Chile.—Sociedad Nacional de Minería.
Stockholm.—Geologiska Förening.
Stratford.—Essex Field-Club.
Sydney.—Linnean Society of New South Wales.
Toronto.—Canadian Institute.
Washington (D.C.).—Academy of Sciences.
—— (—). Carnegie Institution.
Wellington (N.Z.).—'Journal of Science & Technology.'
York.—Yorkshire Philosophical Society.

III. Personal Donors.

Alkins, W. E.
Asselberghs, E.

Backlund, H. G.
Barrow, G.
Bayer, F.
Bell, A.
Buckman, S. S.
Burrard, Sir S. G.

Campbell, J. M.
Cantrill, T. C.
Canu, F.
Chacko, I. C.
Chapman, F.
Choffat, P.
Clarke, F. W.
Cvijič, J.
Cole, G. A. J.
Coomaraswamy, A. K.
Cooper, A. E.
Cooper, E. A.
Cornet, J.
Crook, T.
Curtis, A. H.
Cushman, J. A.

Dall, W. H.
Davies, G. M.
Davis, W. M.
Davison, C.
Dawson, J. W.
Delépine, G.
Dickson, A. A. C.

Earland, A.
Eggleston, J. W.

Ferguson, J. B.
Florin, R.

Guébhard, A.
Giuffrida-Ruggieri, V.

Harmer, F. W.
Haughton, S. H.
Haward, F. N.
Hawkins, H. L.
Henderson, J.
Heron-Allen, E.
Hogben, G.
Howe, M. A.
Hunter, Sir J.
Hunter, J. de D.

Jackson, J. W.
Jackson, R. T.
Jentzsch, A.
Johnson, D. W.
Johnston, M. S.

Katō, T.
Kendall, J. D.

Lacroix, A.
La Touche, T. H. D.
Le Nain, L.
Lowe, H. J.

Martin, E. A.
Merrill, G. P.
Metcalf, M. M.
Moir, J. Reid.
Molyneux, A. J. C.
Morey, G. W.
Morgan, P. G.

Newton, R. B.

Odling, M.
Ojida, L. T.
Oldham, R. D.
Osborn, H. F.

Pilsbury, H. A.
Pinfold, E. S.
Preller, C. S. du Riche.
Pringle, J.

Rathbun, M. J.
Renier, A.
Richards, H. C.

Schuchert, C.
Schwarz, E. H. L.
Sheppard, T.
Sherborn, C. D.
Sherlock, R. L.
Sigg, H.
Springer, F.
Stopes, M. C.

Taylor, G.
Thomas, H. Hamshaw.
Thompson, B.
Thomson, J. A.
Trechmann, C. T.
Tyrrell, J. B.

Vialay, A.

Warren, S. H.
Washington, H. S.
Watts, W. W.
Wherry, E. T.
Whitaker, W.
White, W. P.
Windhausen, R. B. y A.
Woods, H.
Woolacott, D.
Wright, C. H.
Wyer, S. S.

Comparative Statement of the Number of the Society at the Close of the Years 1918 and 1919.

	Dec. 31st, 1918.	Dec. 31st, 1919.
Compounders	213	208
Contributing Fellows	962	986
Non-Contributing Fellows	14	13
	1189	1207
Foreign Members	34	34
Foreign Correspondents	30	28
	1253	1269

Comparative Statement, explanatory of the Alterations in the Number of Fellows, Foreign Members, and Foreign Correspondents at the close of the Years 1918 and 1919.

Number of Compounders, Contributing, and Non-Contributing Fellows, December 31st, 1918		1189
Add Fellows elected during the former year and paid in 1919		7
Add Fellows elected and paid in 1919		64
Add Fellows reinstated		3
		1263
Deduct Compounders deceased	10	
Contributing Fellows deceased	21	
Contributing Fellows resigned	7	
Non-Contributing Fellow deceased	1	
Fellows removed in accordance with Sect. VI, Art. 5, of the Bye-Laws	17	
		56
		1207
Number of Foreign Members and Foreign Correspondents, December 31st, 1918	64	
Deduct Foreign Correspondents deceased	2	
	62	
		62
		1269

Deceased Fellows.

Compounders (10).

Bowring, Col. F. S. [elected 1881].
Corstophine, G. S. [el. 1902].
Crisp, Sir Frank [el. 1880].
Godman, F. DuC. [el. 1873].
Hopkinson, J. [el. 1869].
North, F. W. [el. 1873].
Osborne, J. O. [el. 1881].
Parkinson, C. [el. 1880].
Potter, F. A. [el. 1870].
Safford, J. B. [el. 1867].

Contributing Fellows (21).

Adye, E. H. [elected 1916].
Bailey, T. E. G. [el. 1907].
Balston, W. E. [el. 1872].
Brindley, W. [el. 1888].
Drake, H. C. [el. 1908].
Freeman, J. S. [el. 1911].
Gibson, E. [el. 1913].
Griffith, W. G. [el. 1896].
Hidden, W. E. [el. 1897].
Hill, G. H. [el. 1893].
Kidson, E. R. [el. 1889].
Lambe, L. M. [el. 1890].
Lucas, A. W. [el. 1891].
Meachem, F. G. [el. 1912].
Newton, E. B. B. [el. 1897].
Redwood, Sir Boverton [el. 1894].
Schlæpfer, A. V. M. [el. 1916].
Taylor, E. [el. 1911].
Thackeray, Rev. St. J. [el. 1901].
Wilson, P. O. [el. 1889].
Zealley, A. E. V. [el. 1910].

Non-Contributing Fellow (1).

Ford, J. [elected 1859].

Fellows Resigned (7).

Bean, J. A.
Dodd, C.
Grant, Sir James A.
Parker, T.
Priestley, Major R. E.
Spargo, E.
Spargo, E. J.

Fellows Removed (17).

Browne, P. H.
Edwards, L. W.
Fitton, W. H.
Halberstadt, B.
Hedley, E. H.
Hill, H.
James, B. S.
Komorowicz, Baron M. de.
Lakeland, W. J.
Larcombe, C. O. G.
Lautour, E. A. de.
Leechman, J.
Nichols, H. B.
Ropp, S. G.
Sutherland, J. G.
Swinburne, U. P.
Wight, G.

FOREIGN CORRESPONDENTS DECEASED (2).

Choffat, P. [elected 1914].
Moreno, P. L. [el. 1894].

After the Reports had been read, it was resolved :—

That they be received and entered on the Minutes of the Meeting, and that such parts of them as the Council shall think fit be printed and circulated among the Fellows.

It was afterwards resolved :—

That the thanks of the Society be given to Mr. G. W. Lamplugh, retiring from the office of President.

That the thanks of the Society be given to Prof. Sir John Cadman and Sir Jethro J. H. Teall, retiring from the office of Vice-President and also from the Council, and to the other retiring Members of the Council: Dr. C. W. Andrews, Dr. G. Hickling, and Mr. S. H. Warren.

After the Balloting-Glasses had been closed, and the Lists examined by the Scrutineers, the following gentlemen were declared to have been duly elected as the Officers and Council for the ensuing year :—

OFFICERS AND COUNCIL.—1920.

PRESIDENT.

Richard Dixon Oldham, F.R.S.

VICE-PRESIDENTS.

Prof. Edmund Johnston Garwood, M.A., Sc.D., F.R.S.
George William Lamplugh, F.R.S.
Col. Henry George Lyons, D.Sc., F.R.S.
Prof. John Edward Marr, M.A., Sc.D., F.R.S.

SECRETARIES.

Herbert Henry Thomas, M.A., Sc.D.
Herbert Lapworth, D.Sc., M.Inst.C.E.

FOREIGN SECRETARY.

Sir Archibald Geikie, O.M., K.C.B., D.C.L., LL.D., Sc.D., F.R.S.

TREASURER.

James Vincent Elsden, D.Sc.

COUNCIL.

Francis Arthur Bather, M.A., D.Sc., F.R.S.
Prof. William S. Boulton, D.Sc., Assoc.R.C.Sc.
Robert George Carruthers, F.R.S.E.
Arthur Morley Davies, D.Sc., Assoc.R.C.Sc.
James Vincent Elsden, D.Sc.
Prof. Edmund Johnston Garwood, M.A., Sc.D., F.R.S.
Sir Archibald Geikie, O.M., K.C.B., D.C.L., LL.D., Sc.D., F.R.S.
John Frederick Norman Green, B.A.
Robert Stansfield Herries, M.A.
John Allen Howe, O.B.E., B.Sc.
Prof. Owen Thomas Jones, M.A., D.Sc.
Prof. Percy Fry Kendall, M.Sc.
William Bernard Robinson King, M.A.
George William Lamplugh, F.R.S.
Herbert Lapworth, D.Sc., M.Inst.C.E.
Col. Henry George Lyons, D.Sc., F.R.S.
Prof. John Edward Marr, M.A., Sc.D., F.R.S.
Richard Dixon Oldham, F.R.S.
George Thurland Prior, M.A., D.Sc., F.R.S.
Walter Campbell Smith, M.C., M.A.
Prof. Henry Hurd Swinnerton, D.Sc.
Herbert Henry Thomas, M.A., Sc.D.
Prof. William Whitehead Watts, M.A., Sc.D., LL.D., F.R.S.

LIST OF

THE FOREIGN MEMBERS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1919.

Date of Election.
1884. Commendatore Prof. Giovanni Capellini, *Bologna.*
1886. Prof. Gustav Tschermak, *Vienna.*
1891. Prof. Charles Barrois, *Lille.*
1893. Prof. Waldemar Christofer Brögger, *Christiania.*
1893. Prof. Alfred Gabriel Nathorst, *Stockholm.*
1894. Prof. Edward Salisbury Dana, *New Haven, Conn.* (*U.S.A.*).
1896. Prof. Albert Heim, *Zürich.*
1897. Dr. Hans Reusch, *Christiania.*
1898. Dr. Charles Doolittle Walcott, *Washington, D.C.* (*U.S.A.*).
1899. Prof. Emanuel Kayser, *Marburg.*
1899. M. Ernest Van den Broeck, *Brussels.*
1900. M. Gustave F. Dollfus, *Paris.*
1900. Prof. Paul von Groth, *Munich.*
1900. Dr. Sven Leonhard Törnquist, *Lund.* (*Deceased.*)
1901. Dr. Alexander Petrovich Karpinsky, *Petrograd.*
1901. Prof. Antoine François Alfred Lacroix, *Paris.*
1903. Prof. Albrecht Penck, *Berlin.*
1903. Prof. Anton Koch, *Budapest.*
1904. Prof. Joseph Paxson Iddings, *Brinklow, Maryland* (*U.S.A.*).
1904. Prof. Henry Fairfield Osborn, *New York* (*U.S.A.*).
1905. Prof. Louis Dollo, *Brussels.*
1907. Hofrath Dr. Emil Ernst August Tietze, *Vienna.*
1907. Commendatore Prof. Arturo Issel, *Genoa.*
1908. Prof. Bundjirô Kôtô, *Tokyo.*
1909. Prof. Johan H. L. Vogt, *Christiania.*
1911. Prof. Baron Gerard Jakob De Geer, *Stockholm.*
1911. M. Emmanuel de Margerie, *Strasbourg.*
1912. Prof. Marcellin Boule, *Paris.*
1913. Prof. Johannes Walther, *Halle an der Saale.*
1914. Prof. Friedrich Johann Becke, *Vienna.*
1914. Prof. Thomas Chrowder Chamberlin, *Chicago, Ill.* (*U.S.A.*).
1914. Prof. Franz Julius Lœwinson-Lessing, *Petrograd.*
1914. Prof. Alexis Petrovich Pavlow, *Moscow.*
1914. Prof. William Berryman Scott, *Princeton* (*New Jersey*).

LIST OF

THE FOREIGN CORRESPONDENTS

OF THE GEOLOGICAL SOCIETY OF LONDON, IN 1919.

Date of Election.

1889. Dr. Rogier Diederik Marius Verbeek, *The Hague.*
1890. Geheimer Bergrath Prof. Adolph von Kœnen, *Göttingen.*
1892. Prof. Johann Lehmann, *Weimar.*
1898. Dr. W. H. Dall, *Washington, D.C.* (*U.S.A.*).
1899. Dr. Gerhard Holm, *Stockholm.*
1899. Prof. Theodor Liebisch, *Berlin.*
1900. Prof. Federico Sacco, *Turin.*
1902. Dr. Thorvaldr Thoroddsen, *Copenhagen.*
1904. Dr. Erich Dagobert von Drygalski, *Charlottenburg.*
1904. Prof. Giuseppe de Lorenzo, *Naples.*
1904. The Hon. Frank Springer, *East Las Vegas, New Mexico* (*U.S.A.*).
1904. Dr. Henry Stephens Washington, *Washington, D.C.* (*U.S.A.*).
1906. Prof. John M. Clarke, *Albany, N.Y.* (*U.S.A.*).
1906. Prof. William Morris Davis, *Cambridge, Mass.* (*U.S.A.*).
1906. Dr. Jakob Johannes Sederholm, *Helsingfors.*
1908. Prof. Hans Schardt, *Zürich.*
1909. Dr. Daniel de Cortázar, *Madrid.*
1909. Prof. Maurice Lugeon, *Lausanne.*
1911. Prof. Arvid Gustaf Högbom, *Upsala.*
1911. Prof. Charles Depéret, *Lyons.*
1912. Dr. Frank Wigglesworth Clarke, *Washington, D.C.* (*U.S.A.*).
1912. Dr. Whitman Cross, *Washington, D.C.* (*U.S.A.*).
1912. Baron Ferencz Nopcsa, *Temesmegye* (*Hungary*).
1912. Prof. Karl Diener, *Vienna.*
1912. Prof. Fusakichi Omori, *Tokyo.*
1912. Prof. Ernst Weinschenk, *Munich.*
1913. Dr. Émile Haug, *Paris.*
1913. Dr. Per Johan Holmquist, *Stockholm.*

AWARDS OF THE WOLLASTON MEDAL

UNDER THE CONDITIONS OF THE 'DONATION FUND'

ESTABLISHED BY

WILLIAM HYDE WOLLASTON, M.D., F.R.S., F.G.S., ETC.

'To promote researches concerning the mineral structure of the Earth, and to enable the Council of the Geological Society to reward those individuals of any country by whom such researches may hereafter be made,'—'such individual not being a Member of the Council.'

1831. Mr. William Smith.
1835. Dr. Gideon A. Mantell.
1836. M. Louis Agassiz.
1837. { Capt. T. P. Cautley. / Dr. Hugh Falconer.
1838. Sir Richard Owen.
1839. Prof. C. G. Ehrenberg.
1840. Prof. A. H. Dumont.
1841. M. Adolphe T. Brongniart.
1842. Baron Leopold von Buch.
1843. { M. Élie de Beaumont. / M. P. A. Dufrénoy.
1844. The Rev. W. D. Conybeare.
1845. Prof. John Phillips.
1846. Mr. William Lonsdale.
1847. Dr. Ami Boué.
1848. The Very Rev. W. Buckland.
1849. Sir Joseph Prestwich.
1850. Mr. William Hopkins.
1851. The Rev. Prof. A. Sedgwick.
1852. Dr. W. H. Fitton.
1853. { M. le Vicomte A. d'Archiac. / M. E. de Verneuil.
1854. Sir Richard Griffith.
1855. Sir Henry De la Beche.
1856. Sir William Logan.
1857. M. Joachim Barrande.
1858. { Herr Hermann von Meyer. / Prof. James Hall.
1859. Mr. Charles Darwin.
1860. Mr. Searles V. Wood.
1861. Prof. Dr. H. G. Bronn.
1862. Mr. R. A. C. Godwin-Austen.
1863. Prof. Gustav Bischof.
1864. Sir Roderick Murchison.
1865. Dr. Thomas Davidson.
1866. Sir Charles Lyell.
1867. Mr. G. Poulett Scrope.
1868. Prof. Carl F. Naumann.
1869. Dr. Henry C. Sorby.
1870. Prof. G. P. Deshayes.
1871. Sir Andrew Ramsay.
1872. Prof. James D. Dana.
1873. Sir P. de M. Grey Egerton.
1874. Prof. Oswald Heer.
1875. Prof. L. G. de Koninck
1876. Prof. Thomas H. Huxley.
1877. Mr. Robert Mallet.
1878. Dr. Thomas Wright.
1879. Prof. Bernhard Studer.
1880. Prof. Auguste Daubrée.
1881. Prof. P. Martin Duncan.
1882. Dr. Franz Ritter von Hauer.
1883. Dr. William T. Blanford.
1884. Prof. Albert Jean Gaudry.
1885. Mr. George Busk.
1886. Prof. A. L. O. Descloizeaux.
1887. Mr. John Whitaker Hulke.
1888. Mr. Henry B. Medlicott.
1889. Prof. Thomas George Bonney.
1890. Prof. W. C. Williamson.
1891. Prof. John Wesley Judd.
1892. Baron F. von Richthofen.
1893. Prof. Nevil Story Maskelyne.
1894. Prof. Karl Alfred von Zittel.
1895. Sir Archibald Geikie.
1896. Prof. Eduard Suess.
1897. Mr. Wilfrid H. Hudleston.
1898. Prof. Ferdinand Zirkel.
1899. Prof. Charles Lapworth.
1900. Dr. Grove Karl Gilbert.
1901. Prof. Charles Barrois.
1902. Dr. Friedrich Schmidt.
1903. Prof. Heinrich Rosenbusch.
1904. Prof. Albert Heim.
1905. Sir Jethro J. Harris Teall.
1906. Dr. Henry Woodward.
1907. Prof. William J. Sollas.
1908. Prof. Paul von Groth.
1909. Mr. Horace B. Woodward.
1910. Prof. William B. Scott.
1911. Prof. Waldemar C. Brögger.
1912. Sir Lazarus Fletcher.
1913. The Rev. Osmond Fisher.
1914. Prof. John Edward Marr.
1915. Prof. T. W. Edgeworth David.
1916. Dr. A. P. Karpinsky.
1917. Prof. A. F. A. Lacroix.
1918. Dr. Charles D. Walcott.
1919. Sir Aubrey Strahan.
1920. Prof. G. J. De Geer.

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE WOLLASTON 'DONATION FUND.'

1831. Mr. William Smith.
1833. Mr. William Lonsdale.
1834. M. Louis Agassiz.
1835. Dr. Gideon A. Mantell.
1836. Prof. G. P. Deshayes.
1838. Sir Richard Owen.
1839. Prof. C. G. Ehrenberg.
1840. Mr. J. De Carle Sowerby.
1841. Prof. Edward Forbes.
1842. Prof. John Morris.
1843. Prof. John Morris.
1844. Mr. William Lonsdale.
1845. Mr. Geddes Bain.
1846. Mr. William Lonsdale.
1847. M. Alcide d'Orbigny.
1848. { Cape of Good Hope fossils. / M. Alcide d'Orbigny.
1849. Mr. William Lonsdale.
1850. Prof. John Morris.
1851. M. Joachim Barrande.
1852. Prof. John Morris.
1853. Prof. L. G. de Koninck.
1854. Dr. Samuel P. Woodward.
1855. { Dr. G. Sandberger. / Dr. F. Sandberger.
1856. Prof. G. P. Deshayes.
1857. Dr. Samuel P. Woodward.
1858. Prof. James Hall.
1859. Mr. Charles Peach.
1860. { Prof. T. Rupert Jones. / Mr. W. K. Parker.
1861. Prof. Auguste Daubrée.
1862. Prof. Oswald Heer.
1863. Prof. Ferdinand Senft.
1864. Prof. G. P. Deshayes.
1865. Mr. J. W. Salter
1866. Dr. Henry Woodward.
1867. Mr. W. H. Baily.
1868. M. J. Bosquet.
1869. Dr. William Carruthers.
1870. M. Marie Rouault.
1871. Mr. Robert Etheridge.
1872. Dr. James Croll.
1873. Prof. John Wesley Judd.
1874. Dr. Henri Nyst.
1875. Prof. Louis C. Miall.
1876. Prof. Giuseppe Seguenza.
1877. Mr. Robert Etheridge, jun.
1878. Prof. William J. Sollas.
1879. Mr. Samuel Allport.
1880. Mr. Thomas Davies.
1881. Dr. Ramsay H. Traquair.
1882. Dr. George Jennings Hinde.
1883. Prof. John Milne.
1884. Mr. Edwin Tulley Newton.
1885. Dr. Charles Callaway.
1886. Mr. J. Starkie Gardner.
1887. Dr. Benjamin Neeve Peach.
1888. Dr. John Horne.
1889. Dr. A. Smith Woodward.
1890. Mr. William A. E. Ussher.
1891. Mr. Richard Lydekker.
1892. Mr. Orville Adelbert Derby.
1893. Mr. John George Goodchild.
1894. Sir Aubrey Strahan.
1895. Prof. William W. Watts.
1896. Dr. Alfred Harker.
1897. Dr. Francis Arthur Bather.
1898. Prof. Edmund J. Garwood.
1899. Prof. John B. Harrison.
1900. Dr. George Thurland Prior.
1901. Dr. Arthur Walton Rowe.
1902. Mr. Leonard James Spencer.
1903. Mr. L. L. Belinfante.
1904. Miss Ethel M. R. Wood.
1905. Dr. Henry Howe Bemrose.
1906. Dr. Finlay Lorimer Kitchin.
1907. Dr. Arthur Vaughan.
1908. Dr. Herbert Henry Thomas.
1909. Mr. Arthur J. C. Molyneux.
1910. Mr. Edward B. Bailey.
1911. Prof. Owen Thomas Jones.
1912. Mr. Charles Irving Gardiner.
1913. Mr. William Wickham King.
1914. Mr. R. Bullen Newton.
1915. Mr. Charles Bertie Wedd.
1916. Mr. William Bourke Wright.
1917. Prof. Percy G. H. Boswell.
1918. Mr. Albert Ernest Kitson.
1919. Dr. A. L. Du Toit.
1920. Mr. W. B. R. King.

AWARDS OF THE MURCHISON MEDAL

UNDER THE CONDITIONS OF THE

'MURCHISON GEOLOGICAL FUND,'

ESTABLISHED UNDER THE WILL OF THE LATE

SIR RODERICK IMPEY MURCHISON, Bart., F.R.S., F.G.S

'To be applied in every consecutive year, in such manner as the Council of the Society may deem most useful in advancing Geological Science, whether by granting sums of money to travellers in pursuit of knowledge, to authors of memoirs, or to persons actually employed in any enquiries bearing upon the science of Geology, or in rewarding any such travellers, authors, or other persons, and the Medal to be given to some person to whom such Council shall grant any sum of money or recompense in respect of Geological Science.'

1873. Mr. William Davies.
1874. Dr. J. J. Bigsby.
1875. Mr. W. J. Henwood.
1876. Mr. Alfred R. C. Selwyn.
1877. The Rev. W. B. Clarke.
1878. Prof. Hanns Bruno Geinitz.
1879. Sir Frederick M'Coy.
1880. Mr. Robert Etheridge.
1881. Sir Archibald Geikie.
1882. Prof. Jules Gosselet.
1883. Prof. H. R. Gœppert.
1884. Dr. Henry Woodward.
1885. Dr. Ferdinand von Rœmer.
1886. Mr. William Whitaker.
1887. The Rev. Peter B. Brodie.
1888. Prof. J. S. Newberry.
1889. Prof. James Geikie.
1890. Prof. Edward Hull.
1891. Prof. Waldemar C. Brögger.
1892. Prof. A. H. Green.
1893. The Rev. Osmond Fisher.
1894. Mr. William T. Aveline.
1895. Prof. Gustaf Lindström.
1896. Mr. T. Mellard Reade.
1897. Mr. Horace B. Woodward.
1898. Mr. Thomas F. Jamieson.
1899. { Dr. Benjamin Neeve Peach. / Dr. John Horne.
1900. Baron A. E. Nordenskiöld.
1901. Mr. A. J. Jukes-Browne.
1902. Mr. Frederic W. Harmer.
1903. Dr. Charles Callaway.
1904. Prof. George A. Lebour.
1905. Mr. Edward John Dunn.
1906. Dr. Charles T. Clough.
1907. Dr. Alfred Harker.
1908. Prof. Albert Charles Seward.
1909. Prof. Grenville A. J. Cole.
1910. Prof. Arthur P. Coleman.
1911. Mr. Richard Hill Tiddeman.
1912. Prof. Louis Dollo.
1913. Mr. George Barrow.
1914. Mr. William A. E. Ussher.
1915. Prof. William W. Watts.
1916. Dr. Robert Kidston.
1917. Dr. George F. Matthew.
1918. Mr. Joseph Burr Tyrrell.
1919. Miss Gertrude L. Elles.
1920. Dame E. M. R. Shakespear.

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE 'MURCHISON GEOLOGICAL FUND.'

1873. Prof. Oswald Heer.
1874. { Mr. Alfred Bell.
 Prof. Ralph Tate.
1875. Prof. H. Govier Seeley.
1876. Dr. James Croll.
1877. The Rev. John F. Blake.
1878. Prof. Charles Lapworth.
1879. Mr. James Walker Kirkby.
1880. Mr. Robert Etheridge.
1881. Mr. Frank Rutley.
1882. Prof. Thomas Rupert Jones
1883. Dr. John Young.
1884. Mr. Martin Simpson.
1885. Mr. Horace B. Woodward.
1886. Mr. Clement Reid.
1887. Dr. Robert Kidston.
1888. Mr. Edward Wilson.
1889. Prof. Grenville A. J. Cole.
1890. Mr. Edward B. Wethered.
1891. The Rev. Richard Baron.
1892. Mr. Beeby Thompson.
1893. Mr. Griffith John Williams.
1894. Mr. George Barrow.
1895. Prof. Albert Charles Seward.
1896. Mr. Philip Lake.
1897. Mr. Sydney S. Buckman.
1898. Miss Jane Donald.
1899. Mr. James Bennie.
1900. Mr. A. Vaughan Jennings.
1901. Mr. Thomas S. Hall.
1902. Sir Thomas H. Holland.
1903. Mrs. Elizabeth Gray.
1904. Dr. Arthur Hutchinson.
1905. Prof. Herbert L. Bowman.
1906. Dr. Herbert Lapworth.
1907. Dr. Felix Oswald.
1908. Miss Ethel Gertrude Skeat.
1909. Dr. James Vincent Elsden.
1910. Mr. John Walker Stather.
1911. Mr. Edgar Sterling Cobbold.
1912. Dr. Arthur Morley Davies.
1913. Mr. Ernest E. L. Dixon.
1914. Mr. Frederick Nairn Haward.
1915. Mr. David Cledlyn Evans.
1916. Mr. George Walter Tyrrell.
1917. Dr. William Mackie.
1918. Mr. Thomas Crook.
1919. Mrs. Eleanor M. Reid.
1920. Dr. David Woolacott.

AWARDS OF THE LYELL MEDAL

UNDER THE CONDITIONS OF THE

'LYELL GEOLOGICAL FUND,

ESTABLISHED UNDER THE WILL AND CODICIL OF THE LATE

SIR CHARLES LYELL, Bart., F.R.S., F.G.S.

The Medal 'to be cast in bronze and to be given annually' (or from time to time) 'as a mark of honorary distinction and as an expression on the part of the governing body of the Society that the Medallist (who may be of any country or either sex) has deserved well of the Science,'—'not less than one third of the annual interest [of the fund] to accompany the Medal, the remaining interest to be given in one or more portions, at the discretion of the Council, for the encouragement of Geology or of any of the allied sciences by which they shall consider Geology to have been most materially advanced, either for travelling expenses or for a memoir or paper published, or in progress, and without reference to the sex or nationality of the author, or the language in which any such memoir or paper may be written.'

There is a further provision for suspending the award for one year, and in such case for the awarding of a Medal to 'each of two persons who have been jointly engaged in the same exploration in the same country, or perhaps on allied subjects in different countries, the proportion of interest always not being less to each Medal than one third of the annual interest.'

1876. Prof. John Morris.
1877. Sir James Hector.
1878. Mr. George Busk.
1879. Prof. Edmond Hébert.
1880. Sir John Evans.
1881. Sir J. William Dawson.
1882. Dr. J. Lycett.
1883. Dr. W. B. Carpenter.
1884. Dr. Joseph Leidy.
1885. Prof. H. Govier Seeley.
1886. Mr. William Pengelly.
1887. Mr. Samuel Allport.
1888. Prof. Henry A. Nicholson.
1889. Sir William Boyd Dawkins.
1890. Prof. Thomas Rupert Jones.
1891. Prof. T. McKenny Hughes.
1892. Mr. George H. Morton.
1893. Mr. Edwin Tulley Newton.
1894. Prof. John Milne.
1895. The Rev. John F. Blake.
1896. Dr. A. Smith Woodward.
1897. Dr. George Jennings Hinde.
1898. Prof. Wilhelm Waagen.
1899. Lt.-Gen. C. A. McMahon.
1900. Prof. John Edward Marr.
1901. Dr. Ramsay H. Traquair.
1902. { Prof. Anton Fritsch. / Mr. Richard Lydekker. }
1903. Mr. Frederick W. Rudler.
1904. Prof. Alfred G. Nathorst.
1905. Dr. Hans Reusch.
1906. Prof. Frank Dawson Adams.
1907. Dr. Joseph F. Whiteaves.
1908. Mr. Richard Dixon Oldham.
1909. Prof. Percy Fry Kendall.
1910. Dr. Arthur Vaughan.
1911. { Dr. Francis Arthur Bather. / Dr. Arthur Walton Rowe. }
1912. Mr. Philip Lake.
1913. Mr. Sydney S. Buckman.
1914. Mr. C. S. Middlemiss.
1915. Prof. Edmund J. Garwood.
1916. Dr. Charles W. Andrews.
1917. Dr. Wheelton Hind.
1918. Mr. Henry Woods.
1919. Dr. William Fraser Hume.
1920. Mr. Edward Greenly.

AWARDS

OF THE

BALANCE OF THE PROCEEDS OF THE 'LYELL GEOLOGICAL FUND.'

1876. Prof. John Morris.
1877. Mr. William Pengelly.
1878. Prof. Wilhelm Waagen.
1879. Prof. Henry A. Nicholson.
1879. Dr. Henry Woodward.
1880. Prof. F. A. von Quenstedt.
1881. Prof. Anton Fritsch.
1881. Mr. G. R. Vine.
1882. The Rev. Norman Glass.
1882. Prof. Charles Lapworth.
1883. Mr. P. H. Carpenter.
1883. M. Edmond Rigaux.
1884. Prof. Charles Lapworth.
1885. Mr. Alfred J. Jukes-Browne.
1886. Mr. David Mackintosh.
1887. The Rev. Osmond Fisher.
1888. Dr. Arthur H. Foord.
1888. Mr. Thomas Roberts.
1889. Prof. Louis Dollo.
1890. Mr. C. Davies Sherborn.
1891. Dr. C. I. Forsyth-Major.
1891. Mr. George W. Lamplugh.
1892. Prof. John Walter Gregory.
1892. Mr. Edwin A. Walford.
1893. Miss Catherine A. Raisin.
1893. Mr. Alfred N. Leeds.
1894. Mr. William Hill.
1895. Prof. Percy Fry Kendall.
1895. Mr. Benjamin Harrison.
1896. Dr. William Fraser Hume.
1896. Dr. Charles W. Andrews.
1897. Mr. W. J. Lewis Abbott.
1897. Mr. Joseph Lomas.
1898. Mr. William H. Shrubsole.
1898. Mr. Henry Woods.
1899. Mr. Frederick Chapman.
1899. Mr. John Ward.
1900. Miss Gertrude L. Elles.
1901. Dr. John William Evans.
1901. Mr. Alexander McHenry.
1902. Dr. Wheelton Hind.
1903. Mr. Sydney S. Buckman.
1903. Mr. George Edward Dibley.
1904. Dr. Charles Alfred Matley.
1904. Prof. Sidney Hugh Reynolds.
1905. Dr. E. A. Newell Arber.
1905. Dr. Walcot Gibson.
1906. Prof. W. G. Fearnsides.
1906. Mr. Richard H. Solly.
1907. Mr. T. Crosbee Cantrill.
1907. Mr. Thomas Sheppard.
1908. Prof. T. Franklin Sibly.
1908. Mr. H. J. Osborne White.
1909. Mr. H. Brantwood Maufe.
1909. Mr. Robert G. Carruthers.
1910. Dr. F. R. Cowper Reed.
1910. Dr. Robert Broom.
1911. Prof. Charles Gilbert Cullis.
1912. Dr. Arthur R. Dwerryhouse.
1912. Mr. Robert Heron Rastall.
1913. Mr. Llewellyn Treacher.
1914. The Rev. Walter Howchin.
1914. Mr. John Postlethwaite.
1915. Mr. John Parkinson.
1915. Dr. Lewis Moysey.
1916. Mr. Martin A. C. Hinton.
1916. Mr. Alfred S. Kennard.
1917. Prof. A. Hubert Cox.
1917. Mr. Tressilian C. Nicholas.
1918. Mr. Vincent Charles Illing.
1918. Mr. William Kingdon Spencer.
1919. Mr. John Pringle.
1919. Dr. Stanley Smith.
1920. Dr. John D. Falconer.
1920. Mr. E. S. Pinfold.

AWARDS OF THE BIGSBY MEDAL,

FOUNDED BY THE LATE

DR. J. J. BIGSBY, F.R.S., F.G.S.

To be awarded biennially 'as an acknowledgment of eminent services in any department of Geology, irrespective of the receiver's country; but he must not be older than 45 years at his last birthday, thus probably not too old for further work, and not too young to have done much.'

1877. Prof. Othniel Charles Marsh.
1879. Prof. Edward Drinker Cope.
1881. Prof. Charles Barrois.
1883. Dr. Henry Hicks.
1885. Prof. Alphonse Renard.
1887. Prof. Charles Lapworth.
1889. Sir Jethro J. Harris Teall.
1891. Dr. George Mercer Dawson.
1893. Prof. William J. Sollas.
1895. Dr. Charles D. Walcott.
1897. Mr. Clement Reid.
1899. Prof. T. W. Edgeworth David.
1901. Mr. George W. Lamplugh.
1903. Dr. Henry M. Ami.
1905. Prof. John Walter Gregory.
1907. Dr. Arthur W. Rogers.
1909. Dr. John Smith Flett.
1911. Prof. Othenio Abel.
1913. Sir Thomas H. Holland.
1915. Dr. Henry Hubert Hayden.
1917. Mr. Robert G. Carruthers.
1919. Sir Douglas Mawson.

AWARDS OF THE PRESTWICH MEDAL,

ESTABLISHED UNDER THE WILL OF THE LATE

SIR JOSEPH PRESTWICH, F.R.S., F.G.S.

'To apply the accumulated annual proceeds . . . at the end of every three years, in providing a Gold Medal of the value of Twenty Pounds, which, with the remainder of the proceeds, is to be awarded . . . to the person or persons, either male or female, and either resident in England or abroad, who shall have done well for the advancement of the science of Geology; or, from time to time to accumulate the annual proceeds for a period not exceeding six years, and apply the said accumulated annual proceeds to some object of special research bearing on Stratigraphical or Physical Geology, to be carried out by one single individual or by a Committee; or, failing these objects, to accumulate the annual proceeds for either three or six years, and devote such proceeds to such special purposes as may be decided.'

1903. John Lubbock, Baron Avebury.
1906. Mr. William Whitaker.
1909. Lady (John) Evans.
1912. Library extension.
1915. Prof. Émile Cartailhac.
1918. Sir William Boyd Dawkins.

AWARDS OF THE PROCEEDS OF THE BARLOW-JAMESON FUND,

ESTABLISHED UNDER THE WILL OF THE LATE

DR. H. C. BARLOW, F.G.S.

'The perpetual interest to be applied every two or three years, as may be approved by the Council, to or for the advancement of Geological Science.'

1879. Purchase of microscope.
1881. Purchase of microscope-lamps.
1882. Baron C. von Ettingshausen.
1884. Dr. James Croll.
1884. Prof. Leo Lesquereux.
1886. Dr. H. J. Johnston-Lavis.
1888. Museum.
1890. Mr. W. Jerome Harrison.
1892. Prof. Charles Mayer-Eymar.
1893. Scientific instruments for Capt. E. F. Younghusband.
1894. Dr. Charles Davison.
1896. Mr. Joseph Wright.
1896. Mr. John Storrie.
1898. Mr. Edward Greenly.
1900. Mr. George C. Crick.
1900. Dr. Theodore T. Groom.
1902. Mr. William M. Hutchings.
1904. Mr. H. J. Ll. Beadnell.
1906. Mr. Henry C. Beasley.
1908. 'Grey-Wether' sarsens on Marlborough Downs.
1911. Mr. John Frederick Norman Green.
1913. { Mr. Bernard Smith. / Mr. John Brooke Scrivenor.
1915. Mr. Joseph G. Hamling.
1917. Mr. Henry Dewey.

AWARDS OF THE PROCEEDS OF THE 'DANIEL PIDGEON FUND,'

FOUNDED BY MRS. PIDGEON, IN ACCORDANCE WITH THE WILL OF THE LATE

DANIEL PIDGEON, F.G.S.

'An annual grant derivable from the interest on the Fund, to be used at the discretion of the Council, in whatever way may in their opinion best promote Geological Original Research, their Grantees being in all cases not more than twenty-eight years of age.'

1903. Prof. E. W. Skeats.
1904. Mr. Linsdall Richardson.
1905. Mr. Thomas Vipond Barker.
1906. Miss Helen Drew.
1907. Miss Ida L. Slater.
1908. Mr. James A. Douglas.
1909. Dr. Alexander M. Finlayson.
1910. Mr. Robert Boyle.
1911. Mr. Tressilian C. Nicholas.
1912. Mr. Otway H. Little.
1913. Mr. Roderick U. Sayce.
1914. Prof. Percy G. H. Boswell.
1915. Mr. E. Talbot Paris.
1916. Dr. John K. Charlesworth.
1917. Dr. Arthur Holmes.
1918. Mr. James A. Butterfield.
1920. Miss M. E. J. Chandler.
1920. Mr. L. Dudley Stamp.

Estimates for

INCOME EXPECTED.

	£	s.	d.	£	s.	d.
Compositions	250	0	0			
Admission-Fees, 1920	440	0	0			
				690	0	0
Arrears of Annual Contributions	150	0	0			
Annual Contributions, 1920	2000	0	0			
Annual Contributions in advance	70	0	0			
				2220	0	0
Sale of the Quarterly Journal, including Longmans' Account				200	0	0
Sale of other Publications				10	0	0
Miscellaneous Receipts				30	0	0
Interest on Deposit-Account				15	0	0
Dividends on £2500 India 3 per cent. Stock	75	0	0			
Dividends on £300 London, Brighton, & South Coast Railway 5 per cent. Consolidated Preference Stock	15	0	0			
Dividends on £2250 London & North-Western Railway 4 per cent. Preference Stock	90	0	0			
Dividends on £2800 London & South-Western Railway 4 per cent. Preference Stock	112	0	0			
Dividends on £2072 Midland Railway $2\frac{1}{2}$ per cent. Perpetual Preference Stock	51	16	0			
Dividends on £267 6*s.* 7*d.* Natal 3 per cent. Stock	8	0	0			
Dividends on £500 5 per cent. War Loan 1929–1947	25	0	0			
				376	16	0
Estimated Deficit				£300	0	0
				£3841	16	0

the Year 1920.

EXPENDITURE ESTIMATED.

	£ s. d.	£ s. d.
House-Expenditure:		
Taxes & Fire-Insurance	20 16 0	
Electric Lighting and Maintenance	50 0 0	
Gas	35 0 0	
Fuel	40 0 0	
Furniture and Repairs	40 0 0	
House-Repairs and Maintenance	40 0 0	
Annual Cleaning	15 0 0	
Washing and Sundry Expenses	60 0 0	
Tea at Meetings	25 0 0	
		325 16 0
Salaries and Wages, etc.		1400 0 0
Office-Expenditure:		
Stationery	31 0 0	
Miscellaneous Printing	80 0 0	
Postages and Sundry Expenses	75 0 0	
		186 0 0
Grant to Conjoint Board of Scientific Societies		10 0 0
Library (Books and Binding)		125 0 0
Library Catalogue:		
Cards	10 0 0	
Compilation	50 0 0	
		60 0 0
Publications:		
Quarterly Journal, including Commission on Sale	1200 0 0	
Postage on Journal, Addressing, etc.	80 0 0	
Abstracts of Proceedings, including Postage	180 0 0	
Record of Geological Literature	200 0 0	
List of Fellows	75 0 0	
		1735 0 0
		£3841 16 0

JAMES VINCENT ELSDEN, *Treasurer.*

January 30th, 1920.

RECEIPTS.

	£	s.	d.	£	s.	d.
To Balance in the hands of the Bankers at January 1st, 1919	85	5	8			
,, Balance in the hands of the Clerk at January 1st, 1919	22	11	10			
				107	17	6
,, Compositions				205	8	0
,, Admission-Fees:						
Arrears	44	2	0			
Current	396	18	0			
				441	0	0
,, Arrears of Annual Contributions				243	12	0
,, Annual Contributions for 1919:—						
Resident Fellows	1868	9	6			
,, Annual Contributions in advance	78	15	0			
				1947	4	6
,, Publications:						
Sale of Quarterly Journal: *						
,, Vols. i to lxxiii (less Commission £7 7*s.* 11*d.*)	86	5	3			
,, Vol. lxxiv (less Commission £2 18*s.* 7*d.*)	75	17	0			
				162	2	3
,, Other Publications (less Commission)				9	19	5
,, Miscellaneous Receipts				33	0	6
,, Interest on Deposit				15	14	4
,, Dividends, as received:—						
£2500 India 3 per cent. Stock	75	0	0			
£300 London, Brighton, & South Coast Railway 5 per cent. Consolidated Preference Stock	10	10	0			
£2250 London & North-Western Railway 4 per cent. Preference Stock	63	0	0			
£2800 London & South-Western Railway 4 per cent. Preference Stock	78	8	0			
£2072 Midland Railway 2½ per cent. Perpetual Preference Stock	36	11	8			
£267 6*s.* 7*d.* Natal 3 per cent. Stock	5	12	4			
£500 5 per cent. War Loan 1929–1947	25	0	0			
				294	2	0
,, Income-Tax recovered				79	13	7
,, Grant from the Royal Society for the publication of the List of Geological Literature				100	0	0
				£3639	14	1

* A further sum is due from Messrs. Longmans & Co. for Journal-Sales, etc. £137 15 7

Year ended December 31st, 1919.

PAYMENTS.

	£	s.	d.	£	s.	d.
By House-Expenditure:						
Taxes		15	0			
Fire- and other Insurance	18	10	3			
Electric Lighting and Maintenance	59	0	0			
Gas	35	1	8			
Fuel	42	16	9			
Furniture and Repairs	51	19	3			
House-Repairs and Maintenance	47	3	9			
Annual Cleaning	7	3	0			
Washing and Sundry Expenses	66	10	8			
Tea at Meetings	24	0	6			
				353	0	10
,, Salaries and Wages, etc.:						
Permanent Secretary	442	10	0			
,, half Premium Life-Insurance	10	15	0			
Librarian	252	1	8			
Library Assistant	86	0	0			
Clerk	131	6	8			
Deputy Clerk	71	15	0			
Junior Assistant	22	1	0			
House-Porter and Wife	123	16	6			
Housemaid	68	8	4			
Charwoman and Occasional Assistance	23	0	0			
Accountants' Fee	10	10	0			
Extra Assistance	4	10	6			
,, Office-Expenditure:				1246	14	8
Stationery	23	0	7			
Miscellaneous Printing	84	2	6			
Postages and Sundry Expenses	83	7	5			
				190	10	6
,, Expenditure on account of Grant from Prestwich Fund				3	17	6
,, Library (Books and Binding, etc.)				73	1	0
,, Library-Catalogue:						
Cards		4	6			
Compilation	50	0	0			
				50	4	6
,, Medals (engraving inscriptions)				1	4	0
,, Grant to Conjoint Board of Scientific Societies				10	0	0
,, Publications:						
Quarterly Journal, Vol. lxxiv, Paper, Printing, and Illustrations	828	18	7			
Do. do. Vol. lxxv, Paper, Printing, and Illustrations	109	18	5			
Postage on Journal, Addressing, etc.	81	12	3			
Abstracts, including Postage	179	0	2			
List of Geological Literature (on a/c)	100	0	0			
List of Fellows	34	18	0			
				1334	7	5
,, Balance in the hands of the Bankers at December 31st, 1919 (includes £25 2*s*. 0*d*. not expended of the Grant from the Prestwich Fund for the purchase of Books)	363	13	9			
,, Balance in the hands of the Clerk at December 31st, 1919	12	19	11			
				376	13	8
				£3639	14	1

We have compared this statement with the Books and Accounts presented to us, and find them to agree.

BERNARD SMITH,
S. HAZZLEDINE WARREN, } *Auditors.*

January 30th, 1920. JAMES VINCENT ELSDEN, *Treasurer.*

Statements of Trust-Funds: December 31st, 1919.

'Wollaston Donation Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1919	36	4	1	By Cost of Medal	10	10	0
,, Dividends on the Fund invested in £1073 Hampshire County 3 per cent. Stock	32	3	8	,, Award from the Balance of the Fund	25	14	1
				,, Balance at the Bankers' at December 31st, 1919	32	3	8
	£68	7	9		£68	7	9

'Murchison Geologicai Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1919	24	10	4	By Cost of Medal		11	0
,, Dividends (less Income-Tax) on the Fund invested in £1334 London & North-Western Railway 3 per cent. Debenture Stock	28	0	2	,, Award to the Medallist	10	10	0
,, Income Tax recovered	11	10	1	,, Award from the Balance of the Fund	27	9	5
				,, Balance at the Bankers' at December 31st, 1919	25	10	2
	£64	0	7		£64	0	7

'Lyell Geological Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1919	61	11	1	By Cost of Medal		15	0
,, Dividends on the Fund invested in £2010 1*s.* 0*d.* Metropolitan $3\frac{1}{2}$ per cent. Stock	70	7	0	,, Award to the Medallist	25	0	0
				,, Awards from the Balance of the Fund	53	7	10
				,, Balance at the Bankers' at December 31st, 1919	52	15	3
	£131	18	1		£131	18	1

Bar[illegible]-J[illegible]on Fund Tr[illegible]st [illegible]ccoun[illegible]

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1919........	24	3	3	By Balance at the Bankers' at December 31st, 1919	38	0	7
,, Dividends (less Income-Tax) on the Fund invested in £468 Great Northern Railway 3 per cent. Debenture Stock	9	16	8				
,, Income Tax recovered..........................	4	0	8				
	£38	0	7		£38	0	7

'Bigsby Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1919........	11	0	6	By Cost of Medal	13	4	7
,, Dividends (less Income-Tax) on the Fund invested in £210 Cardiff 3 per cent. Stock	4	8	2	,, Balance at the Bankers' at December 31st, 1919	4	1	11
,, Income Tax recovered	1	17	10				
	£17	6	6		£17	6	6

'Geological Relief Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1919........	77	10	8	By Grants	8	8	0
,, Dividends on the Fund invested in £139 3*s.* 7*d.* India 3 per cent. Stock	4	3	4	,, Balance at the Bankers' at December 31st, 1919	75	8	0
,, Donation from the Rev. H. N. Hutchinson	2	2	0				
	£83	16	0		£83	16	0

'Prestwich Trust Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1919........	18	13	6	By Balance at the Bankers' at December 31st, 1919	39	13	6
,, Dividends on the Fund invested in £700 India 3 per cent. Stock..................................	21	0	0				
	£39	13	6		£39	13	6

'Daniel Pidgeon Fund.' Trust Account.

Receipts.	£	s.	d.	Payments.	£	s.	d.
To Balance at the Bankers' at January 1st, 1919	19	2	1	By Balance at the Bankers' at December 31st, 1919	50	6	2
,, Dividends on the Fund invested in £1019 1*s.* 2*d.* Bristol Corporation 3 per cent. Stock	30	11	4				
,, Interest on Deposit		12	9				
	£50	6	2		£50	6	2

SPECIAL FUNDS.

Hudleston Bequest.

Receipts.	£	s.	d.	Payments.	£	s.	d.	£	s.	d.
To Balance at the Bankers' at January 1st, 1919	150	15	6	By Balance at the Bankers' at December 31st, 1919:						
,, Dividends (less Income-Tax) on the Fund invested in £1000 Canada $3\frac{1}{2}$ per cent. Stock	28	0	0	Current Account	45	8	9			
,, Income Tax recovered	12	0	0	On Deposit	150	0	0			
,, Interest on Deposit	4	13	3					195	8	9
	£195	8	9					£195	8	9

Sorby Bequest.

Receipts.	£	s.	d.	Payments.	£	s.	d.	£	s.	d.
To Balance at the Bankers' at January 1st, 1919	150	15	6	By Balance at the Bankers' at December 31st, 1919:						
,, Dividends (less Income-Tax) on the Fund invested in £1000 Canada $3\frac{1}{2}$ per cent. Stock	28	0	0	Current Account	45	8	9			
,, Income Tax recovered	12	0	0	On Deposit	150	0	0			
,, Interest on Deposit	4	13	3					195	8	9
	£195	8	9					£195	8	9

We have compared this Statement with the Books and Accounts presented to us, and find them to agree.

JAM[illegible] V[illegible]ENT EL[illegible]DE[illegible] *Treasurer.* BERNAR[illegible] [illegible]TH, [illegible] *Audit*[illegible]

Statement relating to the Society's Property.

December 31st, 1919.

	£ s. d.	£ s. d.
Balance in the Bankers' hands, December 31st, 1919 (includes £25 2*s.* 0*d.* not expended of the Grant from the Prestwich Fund)	363 13 9	
Balance in the Clerk's hands, December 31st, 1919	12 19 11	
		376 13 8
Due from Messrs. Longmans & Co., on account of the Quarterly Journal, Vol. LXXIV, etc. ..	137 15 7	
Arrears of Annual Contributions .... (Estimated to produce £150 0*s.* 0*d.*)	191 2 0	
		328 17 7
		£705 11 3
Funded Property, at cost price :—		
£2500 India 3 per cent. Stock	2623 19 0	
£300 London, Brighton, & South Coast Railway 5 per cent. Consolidated Preference Stock	502 15 3	
£2250 London & North-Western Railway 4 per cent. Preference Stock	2898 10 6	
£2800 London & South-Western Railway 4 per cent. Preference Stock	3607 7 6	
£2072 Midland Railway $2\frac{1}{2}$ per cent. Perpetual Preference Stock	1850 19 6	
£267 6*s.* 7*d.* Natal 3 per cent. Stock	250 0 0	
£500 5 per cent. War Loan (1929–1947) ..	475 0 0	
£2000 Canada $3\frac{1}{2}$ per cent. Stock (1930–1950)................................	1982 11 0	
		£14,191 2 9

[NOTE.—*The above amount does not include the value of the Library, Furniture, and stock of unsold Publications. The value of the Funded Property of the Society, at the prices ruling at the close of business on December 31st, 1919, amounted to £*7753 10*s.* 7*d.*]

JAMES VINCENT ELSDEN, *Treasurer.*

January 30th, 1920.

Award of the Wollaston Medal.

In handing the Wollaston Medal, awarded to Prof. Baron Gerard Jakob De Geer, F.M.G.S., to Count H. Wrangel, Minister for Sweden, for transmission to the recipient, the President addressed him as follows:—

Your Excellency,—

By unanimously awarding to Prof. Gerard De Geer its highest distinction, the Wollaston Medal, the Council desires to express its sense of the outstanding value of his work as an investigator in geological science. During nearly 40 years Prof. De Geer has devoted himself assiduously and successfully in many fields to 'researches concerning the mineral structure of the earth.' The memoirs and maps prepared by him for the Geological Survey of Sweden are in themselves a notable achievement. The persistent energy with which he has explored the geology and physiography of Spitsbergen in numerous expeditions from 1882 onward, and the spirit with which he has animated his assistants in the same arduous enterprise, have resulted in important additions to our knowledge of that outlying territory, which, though small in extent, is great in geological significance.

Particularly by his prolonged and intensive study of the Quaternary history of Sweden has Prof. De Geer shown how much may be achieved by patient investigation. Not only has he thrown fresh light upon the changes of level and the changes of climate which your country has undergone since its glaciation, but he has given us new methods, long desired, by which it becomes possible to translate a fragment of geological time into its equivalent term of years. In describing the essence of these methods in his Presidential Address to the Geological Congress at Stockholm, under the title 'A Geochronology of the last 12,000 Years,' Prof. De Geer showed how certain laminated sediments and small recessional moraines had been made to yield a decipherable calendar of annual occurrences. This achievement has still to reach its full effect, but already it has opened up wide possibilities which have stimulated research in many quarters.

Besides his eminent service as an investigator, Prof. De Geer has done much to promote geological science by the stimulus of his own personal enthusiasm upon his students, and by the generous

aid so freely given to fellow-workers in his own and other lands. Those of us who have had the benefit of personal association with him have felt the strength of his devotion to our science and his power in its advancement.

I count it a happy privilege that this Medal should pass through my hands to be conveyed to him, and I will ask Your Excellency in forwarding it, to assure him of our lasting regard.

Count Wrangel read, in reply, the following communication received from Baron G. De Geer:—

'It caused me a very great and agreeable surprise when I received the news that the Council of the Geological Society had awarded to me the Wollaston Medal. A high distinction in itself, a still greater value is certainly lent to it by the fact that it has earlier been conferred upon geologists of such renown and standing as William Smith, Charles Darwin, Charles Lyell, and other leaders of our science. Deeply moved at this sign of encouragement and appreciation of my work, I accept it with the most sincere gratitude, feelings which are intensified by the award being made at the present moment when it appears to me as a symbol of the common interest in Science and the co-operation of ideas among scientific workers all over the world.

'Never will I forget a happy summer—some few years before the tragic events of the last five years—when I, in company with some seventy geologists from all over the world, had the good fortune to work in the Arctic deserts of Spitsbergen, where the structure of this part of the earth is so marvellously exposed. The great joy of deciphering the wonderful features of geological evolution was heightened not only by a brilliant Arctic sun, but also by a most genial spirit of brotherhood joining us all in the same bond of common interest. Memories like these strengthen my belief in a happy future for the commonwealth of Science. For the rest of my life the Wollaston Medal will remain a highly appreciated reminder for me to continue to contribute my modest share to the great work for Science and mankind.

Gerard De Geer,
Stockholm, January 31st, 1920.'

Award of the Murchison Medal.

The President then presented the Murchison Medal to Mrs. Ethel Mary Reader Shakespear, M.B.E., D.Sc., addressing her as follows:—

Mrs. Shakespear,—

The quality and promise of your work on the Graptolites and Graptolite-bearing rocks of this country were recognized at an early stage by the Council. It desires now to mark its appreciation of the results of your perseverance in this work by awarding to you the Murchison Medal.

In collaboration with Dr. Gertrude L. Elles and Prof. C. Lapworth, you have produced a Monograph of British Graptolites which is, and will remain, of the utmost service to all students of the Palæozoic rocks. Your special knowledge has also been most usefully applied to the examination of fossils of this class obtained from distant countries.

Fortified with your palæontological knowledge, your field-work on the Silurian rocks of the Welsh borderland, on ground so familiar to the Founder of this Medal, has taught us much regarding the sequence and correlation of this difficult system. Your results in this field, taken in combination with those of Prof. Lapworth and Dr. Elles in other parts of the sequence, have provided us with a record of the Graptolite succession of Silurian times which has become the standard of reference wherever the rocks of this age are studied. It has been the privilege of the Society to publish most of the papers in which these far-reaching stratigraphical researches are embodied, and your own individual contributions, on the Lower Ludlow formation, in 1900, and on the Tarannon Series, in 1906, are essential links of the chain.

We recognize that the strenuous service which you have been doing for the State during and since the War must take precedence; but may we hope that you will, when possible, resume the studies which have proved so profitable to us?

In handing you this Medal and Award on behalf of the Council, I ask you to accept also my personal congratulation on your success in advancing geological science.

Mrs. Shakespear replied in the following words:—

Mr. President,—

I thank you, Sir, and the Council of the Geological Society for the honour that you have done me in the award of the Murchison Medal—an honour which I value most highly. I only wish that I had done more to deserve a distinction so entirely unexpected; but I must confess that during the past five years my energies have been diverted from the study of Palæozoic geological strata and extinct fossils to the no less complex problem of the obscure workings of Government Departments and modern humanity.

My friend and fellow-worker, Dr. Gertrude Elles, on a similar occasion last year, paid me a generous tribute which I warmly reciprocate.

The debt which we both owe to the inspiration of Prof. Charles Lapworth we alone can truly assess, and it is a great gratification to me, as a specially privileged pupil of his, to feel that I am the medium through which the Geological Society is paying honour once more to a great master and a great-souled man.

It is a special pleasure to me to receive the Medal from the hands of one who has shown me so much kindness, and once again, Sir, I thank you for your kind appreciation.

Award of the Lyell Medal.

In presenting the Lyell Medal to Mr. Edward Greenly, F.G.S., the President addressed him as follows:—

Mr. Greenly,—

You have 'deserved well of the Science.' When you retired from the Geological Survey, 25 years ago, it was only with the intention of devoting yourself unrestrictedly to the advancement of geological knowledge. You chose the complex area of Anglesey as a tract requiring closer investigation, and you set yourself to map the whole island in full geological detail on the 6-inch scale and on a still larger scale where necessary. With admirable perseverance and zest you never swerved from your self-appointed task and carried it through to completion, in your own time and at your own expense. You resolutely denied yourself the volunteer's privilege to pick out the promising parts, and adhered strictly to the method of Survey duty, 'taking the rough with the smooth,' neglecting nothing required to make your work complete in every respect. You have shown the spirit which has animated you, by presenting the results of these many years of labour to the Geological Survey for publication, and by defraying a considerable proportion of the cost. The map and memoir on the table before us are the tangible proofs of your long endeavour, of which you may well be proud. They will remain the standard of reference for all geological questions relating to Anglesey, and contain much besides that will be of universal application.

The Council recognized the value and promise of your work at an early stage, by an award to you of one of the Funds. It now asks you to accept the Lyell Medal 'as a mark of honorary

distinction' and as a token that the expectation which you raised has been fulfilled.

In handing the Medal to you, may I, as an old colleague, who has been in sympathy with your task from its inception, congratulate you upon its successful termination, and express the hope that you will find as good work to do in the future as in the past?

Mr. Greenly replied in the following words:—

Mr. President,—

After such words as you have used, I find it difficult to express my feelings on this occasion. Foremost, however, is a sense of the honour that is implied in recognition by the Council of this historic Society. Next, it is a pleasure to receive it at the hands of a former colleague and a friend of nearly 30 years' standing. Finally, this medal bears the noble name of Lyell, association wherewith cannot but convey a sense of elevation to the mind. As to the methods pursued in the survey of Anglesey, to which you allude, they were learnt under the inspiration of the greatest master of the art of geological surveying, C. T. Clough, whose loss is only too fresh in our memory. In reply to your concluding remark, Sir, I am returning next month to live in Bangor, to take up the mapping of the tract of Carnarvonshire adjacent to Anglesey, and to continue investigation of some of the many unsolved problems of Anglesey itself. As upon the first award bestowed on me by the Council of this Society, so do I look upon the Lyell Medal at once as a high honour, and as an encouragement to further research.

Award from the Wollaston Donation Fund.

The President then presented the Balance of the Proceeds of the Wollaston Donation Fund to Capt. William Bernard Robinson King, B.A., addressing him as follows:—

Captain King,—

The Council has awarded to you the Wollaston Fund in acknowledgment of the brilliant service that you have rendered in applying your geological knowledge to military advantage during the War. Your researches 'concerning the mineral structure of

the Earth on the Western Front have been of an unusual nature, and always of vital consequence. Offering yourself unreservedly for military duty at the outbreak of hostilities, you were fortunate in being soon allotted to a post in which your special qualifications and your field-training on the Geological Survey were called into action. How capably you responded to the call was revealed to us by Col. Edgeworth David in his lecture in this room a few months ago; and we can glean something as to the exacting and difficult conditions of your duties from your excellent paper 'Geological Work on the Western Front' published in the Geographical Journal of October last. By practical demonstration, you have shown that our science is of essential value to the community in War as well as in Peace, and you have secured recognition of the fact in quarters where it had not hitherto been acknowledged.

Knowing the quality of your Survey work, as yet unpublished, I can confidently express our expectation that your further researches during Peace will worthily sustain your record in the War.

Award from the Murchison Geological Fund.

In handing the Balance of the Proceeds of the Murchison Geological Fund, awarded to David Woolacott, D.Sc., to Dr. Herbert Lapworth, for transmission to the recipient, the President addressed him in the following words:—

Dr. Lapworth,—

For over 20 years Dr. Woolacott has worked assiduously for the advancement of our Science in the North-East of England, and has made notable additions to our knowledge in many directions, particularly in respect of the composition and structure of the Permian rocks of Durham, and of the North-Eastern Glacial drifts. In his contribution to our Journal in 1905 on the Superficial deposits & Preglacial valleys of the Northumberland & Durham Coalfield, he brought together a mass of information respecting the drift-filled 'washes' of the district, which is of practical as well as of scientific consequence. His numerous papers on the Permian formation which have appeared from time to time in the Geological Magazine, the Proceedings of the Geologists' Association (1913), and the publications of local Societies have explained

many of the anomalous features of these difficult rocks. That his physiographical studies have also been effective, is proved by his contribution to the Royal Geographical Society (1907) on the 'Origin & Influence of the chief Physical Features of Northumberland & Durham,' and by other writings.

In recognition of the usefulness of the work already done the Council has awarded to Dr. Woolacott the Murchison Fund.

May I request that, in transmitting it to him, you will convey our hope that his present travels will prove in every way beneficial to him, and that he will resume his fruitful investigations on his return?

Awards from the Lyell Geological Fund.

The President then handed a moiety of the Balance of the Proceeds of the Lyell Geological Fund, awarded to John Downie Falconer, D.Sc., to Prof. E. J. Garwood for transmission to the recipient, addressing him as follows:—

Prof. Garwood,—

A moiety of the Lyell Fund has been awarded by the Council to Dr. Falconer in recognition of his important contributions to our knowledge of Northern Nigeria and of his excellent work in Scotland. In his description of the Igneous Geology of the Bathgate & Linlithgow Hills (1905–6) and of Ardrossan (1907) he proved his capability as an investigator, and afterwards took full advantage of the wider scope afforded to him in Western Africa. By several papers and by his comprehensive book on the Geology and Geography of Northern Nigeria (1911) he has aided materially in throwing light upon a part of the interior of the Continent, so long proverbially 'dark.' With a sharp eye for surface-relief, Dr. Falconer has devoted special attention to the physiographical studies in which Geology and Geography are interlinked, and his recent suggestive classification of land-forms (1915) is a brave attempt to fix the relations and nomenclature of surface-features in general.

I will ask you, in conveying this Award to Dr. Falconer, to assure him that we shall watch his further progress in Africa or elsewhere with sympathetic interest.

In handing the other moiety of the Balance of the Proceeds of the Lyell Geological Fund, awarded to Mr. Ernest Sheppard Pinfold, F.G.S., to Dr. Herbert H. Thomas for transmission to the recipient, the President addressed him in the following words :—

Dr. Thomas,—

In awarding a moiety of the Lyell Fund to Mr. E. S. Pinfold the Council desires to mark its appreciation of the value of his geological work in Burmah and India. During the course of his duties in economic research in the oil-fields, he has kept the purely scientific interest of his investigations steadily in view, as well as their commercial application. He has done much to clear up the stratigraphy of the Tertiary strata of Upper Burmah, and his contribution to our knowledge of the structure and stratigraphy of the North-West Punjab has been deemed of sufficient importance to be published in the Records of the Geological Survey of India.

The Council hopes that this Award may serve, not only as a recognition, but also as a stimulus to him to continue his geological researches.

THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

George William Lamplugh, F.R.S.

It becomes once more my regretful duty to review the roll of Fellows lost to us by Death. With the passing of the War-cloud the list is not so heavy as of late years, but it contains many names which you will desire me to commemorate. In attempting to do so, I have received assistance from several friends, especially from Dr. A. Smith Woodward, Mr. R. Bullen Newton, Dr. F. A. Bather, and Prof. W. S. Boulton.

First we have to deplore two talented Fellows lost in the aftermath of the War.

Captain Tom Esmond Geoffrey Bailey was the member of a patriotic family of six brothers, all of whom served abroad in the Voluntary Army. Their record is heroic, and characteristic of their time. Four of them gained the Military Cross; two lost their lives in action; one died subsequently, while serving as Principal Medical Officer in the former German territory of East Africa; and another, eminent in our science, was twice severely wounded.

At the outbreak of hostilities the one of whom I have now to speak came home from his geological work in Borneo, and entered the Army. During hard and distinguished service as an officer in France, from 1915 to 1918, he was promoted and recommended for honours for his conduct at the battle of the Somme in 1916, and was severely wounded in leading a forlorn hope at Arras in 1917. Towards the end of 1918 he went to North Russia, and fell fighting there on April 2nd, 1919, while advancing unsupported on machine-guns which had opened up unexpectedly on his path. He had been awarded the Military Cross for his behaviour in action not many days before, but did not live to know of it. In his life and death he was typical of Britain's best.

Born on April 15th, 1883, he was educated at Kendal and Dulwich, and afterwards at Cambridge where he graduated (1902–5). He was elected into our Society in 1907. Between 1906 and 1908 he was occupied in a mineral survey of Nyasaland under the auspices of the Imperial Institute, having for his fellow-worker Dr. A. R. Andrew. As an outcome of this work Andrew & Bailey submitted a paper to our Society on the Geology of Nyasaland, which was published in the Quarterly Journal in

1910 (vol. lxvi, pp. 189–253), and is an important contribution to our knowledge of Central Africa. From 1909 to 1912 Bailey was employed in research in the oil-fields of Burmah and Borneo. He was 36 years old when he fell. He had seen and learnt much, and it is an aggravation of our loss that he should have been cut down at the very last stage of the fighting.

Ernest Bennett Brierley Newton, M.Inst.C.E., a prominent municipal engineer, was born in Chester in 1873, received his early education at Eccles, and, after matriculating at London University in 1890, was trained in his profession at Manchester and Carlisle. He became a Fellow of our Society in 1897. In 1898 he entered the service of the Metropolitan Borough of Paddington, and was promoted to the post of Borough Engineer and Surveyor in 1901, being at that time one of the youngest engineers to hold so important a position in the municipal world. He continued in this office until the War, joining the Army early in 1915 with a commission in the Glamorgan Fortress Engineers. In 1916 he went to France as Lieutenant, Royal Engineers, and survived until 1918, when he was reported missing, and was eventually recorded as 'killed in action' on April 10th, 1918, at Armentières, at the age of 45 years. While at Carlisle he executed a series of archæological surveys in connexion with the Roman Wall. He was also the author of a work on sewerage schemes, and contributed articles on cognate subjects to the professional journals. He held office in many technical societies, and possessed qualities which marked him for further advancement.

From the Foreign List we have lost two Correspondents, Dr. F. P. Moreno and Dr. Paul Choffat.

Dr. Francisco P. Moreno, who was elected a Foreign Correspondent in 1894, accomplished much for the promotion of natural science in the Argentine Republic. He was born in Buenos Aires on May 31st, 1852, and began early to follow his inclination to travel and make natural-history collections. So long ago as 1874 he wrote on the prehistoric cemeteries of Patagonia in the 'Revue d'Anthropologie,' and three years later he had already collected so important a series of anthropological and archæological specimens that the Argentine Government accepted them to form the basis of a new Anthropological & Archæological Museum in Buenos

Aires. He continued his systematic explorations of Patagonia and the Southern Andes until 1884, when he was entrusted with the organization of a great new museum in La Plata, the recently-founded provincial capital. The building and installation of this Museum were completed in 1889, and to it were transferred al Dr. Moreno's collections, with his library, besides a remarkable series of skeletons of the Pleistocene mammals of the Pampa discovered during the excavation of the docks at La Plata. The geological and palæontological publications of the La Plata Museum, prepared under the direction of Dr. Moreno, are among the most important contributions to our knowledge of South America. In 1899 Dr. Moreno visited London as Argentine Commissioner in connexion with the Argentine-Chilean boundary dispute, which had been referred for arbitration to the British Crown, and in 1900 he issued four valuable volumes of evidence, illustrated with beautiful photographs of the country. For a few years longer he continued at La Plata to promote researches into the natural history of the Republic, and eventually retired to Buenos Aires, where he still rendered public service by applying his ripe experience to the problems of education. His published writings give little idea of the extent of his work, for he was as generous with his learning as with his personal property, and he was never happier than when inspiring others to prosecute scientific research. In 1907 Dr. Moreno received the Founder's Medal from the Royal Geographical Society, of which he was an Honorary Corresponding Member. He was also a Corresponding Member of the Zoological Society of London. [A. S. W.]

By the death of Prof. Paul Choffat at Lisbon on June 6th, 1919, in his 71st year, the Society has lost one of its most distinguished Foreign Correspondents. Choffat was born in 1849, and his earlier career was passed in Switzerland, where he qualified as a Doctor of Science of the University of Zurich, being subsequently appointed Professor of Geology in the Polytechnic School of that city. During this period he commenced active research-work in geology, carrying out extensive investigations on the structure of the Jura region of Switzerland and France, the results of which were embodied in a number of papers full of new and valuable details of palæontological and tectonic interest. It was this sound experience of field-work, combined with a facility for writing, that enabled Choffat later on to accept an important position on the

Geological Survey of Portugal, then under the Directorship of Prof. J. F. N. Delgado; with that Survey he came to be connected for the remainder of his life, a period of nearly 40 years. His actual appointment to the Portuguese Survey was probably made about 1885, although he was engaged in a temporary capacity in 1880, when the Survey published his first memoir on the 'Terrains Jurassiques du Portugal,' which embraced a stratigraphic and palæontological account of the Liassic and Dogger rocks occurring north of the Tagus. Then followed his memoirs on the Jurassic palæontology of Portugal, in which he described the Pelecypoda and Cephalopoda, illustrated by nearly forty quarto plates, the whole of which was issued in parts between 1885 and 1893. In this he introduced the name 'Lusitanian' for a group of rocks lying between the topmost Callovian and the Neo-Jurassic, a part of which is rich in fossils, particularly the ammonite *Perisphinctes* and the pelecypod genus *Trichites*.

The history of the Cretaceous rocks of Portugal claimed also a large share of his attention, and his memoirs on those groups are models of analytical enquiry and accuracy; the essentially stratigraphical part of the subject, occupying nearly 350 pages of text and containing valuable faunistic tables, sections, and maps, was published in 1885 and 1900. The strictly palæontological memoirs dealing with the Cretaceous faunas were issued between 1886 and 1902, and, as before, the various life-groups, chiefly the Mollusca, were profusely illustrated, described, and horizoned.

The faunas of the Tertiary and later deposits of Portugal had been mostly described by others, so that Choffat contributed only a small amount of literature on this subject, although mention may be made of his paper 'L'Homme Tertiaire en Portugal,' published in 1880, which, however, never claimed particular attention on account of the imperfection of some of the details of the subject. No notice of Choffat would be complete without a reference to his work on the geology of the Portuguese African possessions. His masterly memoirs of 1903 and 1905, dealing with the Angola region of South-West Africa and the Mozambique territory of South-East Africa, greatly contributed to solve many interesting problems connected with the stratigraphy of those areas of the African continent.

On collateral subjects connected with the geology of Portugal, he published communications respecting erosion, seismology, and hydrology, besides compiling a series of most useful bibliographies.

Many specific names were made in his honour, as well as genera, the latter including *Choffatia*, a Jurassic ammonite established by Siemiradski in 1898, and Schlumberger's *Choffatella*, founded in 1905 for a Cretaceous genus of Foraminifera.

He contributed some 150 papers and memoirs to geological literature, published between 1874 and 1918. He was a member of many of the learned societies of Europe, including the Geological Society of France, to which he was elected in 1875. His election as a Foreign Correspondent of our Society took place in 1914. For his eminent geological services to his adopted country of Portugal he was the recipient of greatly-coveted decorations. [R. B. N.]

The sudden death of John Hopkinson on July 5th last, in his 74th year, has deprived us of a worker whose activities were beneficial in many branches of science besides our own. Born at Leeds in 1844, Hopkinson came while young to reside in Hertfordshire, first at St. Albans and later at Watford. Engaged in business during the greater part of his life, as a member of the well-known firm of piano-manufacturers, he devoted the whole of his leisure to scientific pursuits, and was a prominent example of the amateur worker to whom British science owes so much and for whom it has always been distinguished. Zealous in the study of Nature in all its aspects, he did excellent work as an original observer, and was, besides, ever ready to bring his practical training to bear upon the promotion and welfare of the scientific associations which have rendered indispensable service in the spread and advancement of knowledge. He was the organizer and staunch supporter of the Hertfordshire Natural History Society (1875) and of the Conference of Delegates connected with the British Association (1880), serving both bodies in varied capacities. He took a prominent part in founding the County Museum for Hertfordshire at St. Albans. He was active in the Ray Society, being its Treasurer from 1899 to 1902, and its Secretary from that time until his death. His Fellowship in our own Society was of 50 years' standing (he was elected in 1869), and he served on our Council from 1884 to 1888. He was likewise a Fellow of the Linnean, Zoological, Microscopical, and Meteorological Societies, and an Associate of the Institute of Civil Engineers.

Hopkinson was one of the pioneers of the study of graptolites and their zonal distribution. He was joint author with Prof. C. Lapworth of an important paper on the Graptolites of the Arenig

and Llandeilo Rocks of St. David's, which appeared in our Quarterly Journal in 1875; and he published several other papers on graptolites in the 'Geological Magazine' between 1870 and 1881. He also wrote much on the general geology of Hertfordshire, and contributed several geological papers to the meetings of the British Association. Through the Ray Society he published a 'Bibliography of the Tunicata' (1913), and was part author (with J. Cash & G. H. Wailes) of a Monograph on 'British Freshwater Rhizopoda,' of which three volumes have already been issued. But it is in the Transactions of the Hertfordshire Natural History Society that the scope and vigour of his scientific activity and nature-lore are most strikingly apparent. Here are contained annual reports from 1876 onwards, in which are given his continuous observations on the meteorology and phenology of the county, together with the results of his prolonged studies of its land-mollusca, birds, insects, bournes, scientific literature, and history. He was, indeed, an unfailing authority on all scientific matters pertaining to the county, and his information was placed at the disposal of every earnest worker. The kindly deference of his manner concealed a breadth of knowledge and culture which long acquaintanceship alone could discover and appreciate.[1]

We shall all miss the kindly presence of Alfred Prentice Young, Ph.D., whose constant attendance at the meetings of our own and kindred Societies during many years made him personally known to a wide circle of geologists. Dr. Young was born in 1841, and was educated at the Denmark Hill Grammar School, Harvard College, and the Normal School of Science. In 1857 he entered the Indian Navy as midshipman, and four years later was transferred to the Bombay Marine Service, where he rose to the rank of Commander. In 1864 he acted as Surveyor in the Telegraph Expedition in the Persian Gulf, and in 1866 he was engaged on the survey of Butcher's Island and adjacent shores. Subsequently he was employed in the Revenue Survey and Assessment, being stationed mainly at Poona, but serving for some time on Famine duty in Dharwar in 1877. At the time of his retirement from the Indian service in 1893 he held the post of Acting Superintendent on the Deccan Revenue Survey. His predilection for geology appears to have been aroused in early life, and was

[1] An excellent photograph of John Hopkinson is reproduced in the obituary notice in the 'Geological Magazine' for September 1919.

fostered by later studies at the Royal School of Mines, and at Munich where he obtained his degree. It was not, however, until his retirement that he was able to follow his bent freely, and our science then became his predominant interest. Participating in geological excursions far and near, he gained a broad knowledge of current problems in various branches of geology, and was always ready to discuss them. He undertook some original research in the Tyrol, the results of which are contained in a paper on 'The Structure and Physiography of the Tarnthal Mass,' published in our Quarterly Journal for 1908, and in two excellently-illustrated papers in the 'Geological Magazine' for 1909 & 1910. He was in Austria when the War broke out, and was placed under arrest and held for a short time in confinement. He was elected into our Society in 1884.

Reserved and unobtrusive, Dr. Young went quietly through life, making many friends, but never inviting intimacy. The dogged courage with which he overcame all physical obstacles in the pursuit of his favourite study was conspicuous almost to the last. He died on December 8th, 1919, at the age of 78 years.

Dr. Frederick Du Cane Godman, who became a Fellow of our Society in 1873, was a naturalist of the widest sympathies, who devoted himself chiefly to systematic zoology, but appreciated the importance of taking geology into account before attempting broad generalizations. He was born at Godalming in January 1834, and died in London on February 19th, 1919. Being possessed of ample means, he travelled widely in pursuit of his favourite studies, and made great collections, especially of birds and insects, which he gave to the British Museum. When Darwin's 'Origin of Species' was published in 1859, Godman was at Trinity College, Cambridge, where he met Osbert Salvin. The two young naturalists were deeply impressed by the new views expounded in Darwin's work, and at once determined to investigate the problems of geographical distribution. Central America seemed to them to be an especially promising region for study, and in 1861 they proceeded together to Guatemala, where Salvin had already collected birds and plants. By 1876 they had made so much progress that they decided to publish a great work, 'Biologia Centrali-Americana,' describing the animals and plants of Central America in a most exhaustive manner. They employed skilled collectors, they also enlisted the services of many eminent naturalists as contributors, and the

undertaking occupied them for the rest of their lives. Salvin died in 1898, and for the last twenty years Godman edited the work alone, eventually completing it in 63 quarto volumes. It forms the largest personal contribution to natural history that has ever been made. Godman also examined the fauna and flora of the Azores, which he described in 1870, and made some noteworthy contributions to our knowledge of the Canaries and Madeira. As a Trustee of the British Museum, he stimulated research in many directions, and he was especially interested in the modern discoveries of remains of extinct vertebrate animals in various parts of the world. He was elected a Fellow of the Royal Society in 1882, and the Gold Medal of the Linnean Society was awarded to him in 1918. [A. S. W.]

Sir Boverton Redwood, Bart., D.Sc., F.C.S., Assoc.Inst.C.E., who was elected a Fellow of our Society in 1894, was famous as an authority on petroleum. Born in London on April 26th, 1846, he completed his education at University College School, and entered the laboratory of his father, who was Professor of Chemistry to the Pharmaceutical Society. In 1869 he was appointed Secretary to the Petroleum Association, and thenceforward devoted all his energies to the study of petroleum in all its aspects, which necessarily led him to consider the geological conditions under which it occurred. During his professional career as an expert, he visited the principal oil-fields of the world, and compiled from all sources a mass of information on the subject, which he embodied in his well-known 'Treatise on Petroleum,' first published in 1896, with later editions, greatly enlarged, in 1906 and 1913. He took a leading part in the foundation of the Institution of Petroleum Technologists, and served as its first President in 1914–16. He was knighted in 1905, and created a Baronet in 1911. He died at his London residence on June 4th, 1919, at the age of 73 years.

Sir Frank Crisp, Bart., the senior partner in the well-known firm of solicitors, Ashurst, Morris, Crisp, & Co., was born on October 25th, 1843. Early in life he acquired an interest in the microscope. He made a large collection of instruments, a remarkably complete library of works dealing with the subject, and was for many years Honorary Secretary of the Royal Microscopical Society. Another of his interests was Botany. His Alpine garden at Henley-on-Thames is celebrated, and he was

Treasurer of the Linnean Society for 24 years. He joined our Society in 1880. He was knighted on November 9th, 1907, and created a Baronet on February 5th, 1913. He died at his seat, Friar Park, Henley-on-Thames, on April 29th, 1919.

[H. W. M.]

LAWRENCE M. LAMBE, elected a Fellow in 1890, was a Graduate of the Military College, Kingston (Ontario). He entered the Geological Survey of Canada as a draughtsman, and worked under the late Dr. Whiteaves, also for a time with Mr. Foord, whom he succeeded. He was for some years Honorary Treasurer of the Royal Society of Canada, and also served as President of Section iv (Geological & Biological Sciences). He published a work on the Atlantic Coast Sponges, and afterwards devoted much attention to the Palæozoic Corals of Canada. His later papers are mostly on fossil Vertebrates, particularly on the Cretaceous Reptilia of Alberta. Many of his papers are of great interest, and they are as a rule excellently illustrated.

Lambe died of pneumonia on March 12th, 1919, having served on the staff of the Geological Survey of Canada for 35 years.

[C. W. A.]

WILLIAM EARL HIDDEN of Ocean Grove, New Jersey (U.S.A.), elected in 1897, was born on February 16th, 1853, at Providence (R.I.). He was widely known for his work in American mineralogy, particularly in respect of the rarer minerals and gem-stones of the Southern States, of which he was an assiduous collector. He published many articles and notes on American minerals and on meteorites in the American Journal of Science, the Transactions of the New York Academy of Sciences, and other journals. An emerald-green variety of spodumene used as a gem was named 'hiddenite' after him. He died at his home, Ocean Grove, on June 12th, 1918, at the age of 65 years.[1]

ERNEST HOWARD ADYE, elected in 1916, was born on March 10th, 1857, and died abroad on June 15th, 1918. He was much interested in petrography, and produced several illustrated works on the subject, including a '20th Century Atlas of Microscopical Petrography,' published in instalments between 1904 and 1906; 'Studies in Micro-Petrography,' of which vol. i, pt. i appeared in

[1] A good account of Hidden's life and work, written by G. F. Kunz, may be found in 'The American Mineralogist' for October & November 1919.

1906; and 'Modern Lithology, illustrated and defined,' published in 1907. Later he was employed in India and Burma, mainly in economic geology, and was for a time Director of the Geological Survey of Porbandar State. In India he published some Reports on the Economic Geology of Navangar State (1914) and of Porbandar State (1917).

William Brindley, whose intimate knowledge of antique marbles and other ornamental stones rendered him a leading authority in matters relating to ancient architecture, died at his residence at Boscombe on February 10th, 1919, in his 87th year, after a Fellowship dating from 1888. He was born in Derbyshire in 1832, and educated locally. Very early in life he developed a remarkable talent for sketching, designing, and carving, and overcame great difficulties in the pursuit of his bent. Coming to London while still young, he soon became known as a clever carver, and carried out many important works. Later, as a member of the firm of Farmer & Brindley, he came into touch with the leading architects of the day, and his opinion was much sought in questions of material and architectural art. When circumstances permitted, he travelled widely in Europe and Northern Africa in search of the sources of antique decorative rocks, and he rediscovered the quarries of Imperial Egyptian porphyry, Verde Antico, and Greek Cipollino marbles. He was joint-author with Mr. W. S. Weatherley of an elaborate book on 'Ancient Sepulchral Monuments,' published in 1887; and he contributed to the Royal Institute of British Architects papers on 'Marble, its Uses as suggested by the Past,' 'The Ancient Quarries of Egypt,' and 'The Modern Aspects of Marble Work in Architecture.' A man of indomitable energy and wide interests, he spared no pains to amass knowledge connected with his life's work, and in doing so gained much besides.

By the death of Frederick George Meachem on May 25th, 1919, the mining world of the Midlands has lost a notable figure. Born on September 11th, 1860, he commenced his training as a mining engineer under his father, Mr. Isaac Meachem, when the latter was engaged in sinking the Hamstead Pit, Great Barr, near Birmingham; and on his father's death the son became manager of the colliery. F. G. Meachem formed one of the rescue-party at the time of the great colliery-disaster at Hamstead, which occurred just prior to his father's death. He was the first to

point out that some of the upper red measures at Hamstead properly belong to the Coal Measures, and it was his paper, read at the British Association at Birmingham in 1886, which directed Dr. Kidston's attention to the flora of these Upper Coal-Measure rocks. About 15 years ago Meachem resigned his colliery managership, and commenced private practice as a mining engineer. He was elected a Fellow of our Society in 1912. [W. S. B.]

Ernest Gibson, who became a Fellow in 1913, was both a Scotsman and an Argentine citizen, deeply interested in natural science, and always eager to use his means and influence for its promotion. For some time he was a member of the council of the Palæontographical Society, and he also took an active part in the work of the Zoological Society and the British Ornithologists' Union.

The Rev. Francis St. John Thackeray, M.A., F.S.A., Vicar of Mapledurham for many years, and previously a classical master at Eton College, died on July 14th, 1919, in his 87th year. He was elected a Fellow of our Society in 1901, and was deeply interested in geology, although not undertaking definite research. He was a most successful collector of fossils, from both British and foreign localities, and bequeathed a collection, containing many hundreds of specimens from most of the geological formations, to the Eton-College Museum. A small and interesting series of fossils from the Cretaceous opalized deposits of New South Wales, including a few recently-described new species of Mollusca, he generously left to the Geological Department of the British Museum. He was first cousin to the famous novelist. [R. B. N.]

Cyril Parkinson was born at Hexgreave Park, near Southwell (Nottinghamshire), and died in London on August 20th, 1919, at the age of 65. During five years' residence in the Isle of Wight (1875–80) he made a collection of fossils, which was acquired by the British Museum (Natural History). He became a Fellow of our Society in 1880. He was a member of the Worcester Naturalists' Club, and an occasional contributor to 'Borrow's Worcester Journal' on natural history subjects. He also contributed articles to various periodicals on natural history, geology, and botany, and brought out a handbook of the Isle of Wight Marine Algæ in collaboration with Mrs. O'Brien, of Ventnor.

Among our other losses, I have to mention that of one of our oldest Fellows, John Ford, of Potter's Bar, who was elected in 1859, and died on July 2nd, 1919, after a Fellowship of 60 years; also of Col. F. S. Bowring, C.B., R.E. (retired), of Chislehurst, who was in Army service from 1869 to 1904, gaining distinctions in the Afghan War of 1877–80, in the Burmese Expedition of 1886–87, and in China, 1900. He was elected a Fellow of our Society in 1881, and died on March 23rd, 1919, in his 72nd year.

Another eminent worker, at one time a Fellow of the Society, was Robert Etheridge (son of a former President, the distinguished palæontologist of the same name), whose death occurred at Colo Vale, near Sydney, on January 4th, 1920, in his 74th year. Etheridge early took up geological work in Australia as a member of the first Geological Survey of Victoria, under the direction of A. R. C. Selwyn, in the middle 'sixties; but later he returned home, and was appointed Palæontologist to the Geological Survey of Scotland, his father being then Palæontologist to the English Survey. During the 'seventies of the last century he contributed several palæontological papers to our Journal, and, in 1877, received an award from our Wollaston Donation Fund in recognition of his work. When the natural-history collections of the nation were removed from Bloomsbury to the new Natural History Museum in Cromwell Road, the two Etheridges were brought on to the staff of the Geological Department, where the memory still remains of the vigorous actions and language of 'R. E. junior.' The chief piece of palæontological work accomplished by Etheridge while in this position was a Catalogue of the Blastoidea, in which he had the cooperation of P. Herbert Carpenter.

Australia, however, was never far away from the thoughts of Etheridge. He compiled a useful bibliography of Australian geology, and studied fossils sent to him from Queensland by his erstwhile Edinburgh colleague, Mr. R. Logan Jack. This eventually resulted in a large work by the two friends on 'The Geology & Palæontology of Queensland & New Guinea' (1898). Meanwhile, in 1887, Etheridge returned to Australia as Palæontologist to the Geological Survey of New South Wales and to the Australian Museum, Sydney. Here he remained and worked for the remaining 33 years of his life, becoming Director of the Museum in 1895. At the Mines Department he started the well-

known 'Records of the Geological Survey,' and published from time to time important memoirs on the fossils of the older rocks. At the Museum, Etheridge threw himself with his wonted vigour into the arrangement and display of the collections, and founded the 'Records of the Australian Museum.' Through his efforts, also, a fine series of ethnological exhibits from the Pacific Islands was accumulated, and a magnificent display of native work was installed in the Museum galleries.

Etheridge received the Clarke Memorial Medal from the Royal Society of New South Wales in 1895, and the Mueller Memorial Medal from the Australian Association for the Advancement of Science in 1911. His name is widely known, not only from the various fossils that have been named after him, but also from the Antarctic glacier, the lofty peak on the Kosciusko Plateau, and the Etheridge Goldfield in North Queensland. His colleagues will cherish his memory as that of a sound and untiring worker, and a man always ready to help his fellows. [F. A. B.]

It is incumbent upon me also to speak in memory of ALEXANDER MCHENRY, who, although not a Fellow of this Society, was a contributor to our Journal, and well known personally to many of us; while the value of his work was recognized by the Council in 1901 by the Award of a moiety of the Lyell Fund. Born at Ballycastle (Antrim), in 1844, McHenry, while living in Dublin in his youth, had his interest in geology aroused by the evening lectures of Beete Jukes, who, finding an apt student, obtained for him in 1861 the post of Specimen-Collector on the Geological Survey in Ireland. In the course of his duties he acquired a far-reaching knowledge of Irish rocks and fossils, which continued to increase throughout his career. In 1877 he was promoted to be Assistant-Geologist, and to the rank of Geologist in 1890. He took part in mapping the difficult granitic and metamorphic rocks in North-West Mayo, and worked later on the similar complex in Donegal. At other times he was engaged on the Devonian and Carboniferous rocks of Cork and Kerry, and on the Ballycastle district and other areas in County Antrim. On the completion of the primary 1-inch map of Ireland, he was occupied with Prof. W. W. Watts in a revision of some of the tracts of igneous and gneissose rocks, and with Mr. J. R. Kilroe in tracing the division between Silurian and Ordovician in the country generally. The 'Guide to the Collection of Rocks

and Fossils belonging to the Geological Survey of Ireland,' produced in collaboration with Prof. Watts in 1895 (new ed. 1898), comprises much more than its title implies, and constitutes, in fact, an excellent general sketch of the geology of Ireland. McHenry also participated in the later mapping of the Drifts in the country around Dublin, Belfast, Cork, Limerick, and Londonderry (1901–1906), and contributed subsequently to the preparation of a special memoir on the Interbasaltic Rocks (Iron-Ores & Bauxites) of North-East Ireland (1912).

Most of McHenry's work was published officially; but, besides his contribution (jointly with Mr. J. R. Kilroe) to our Journal in 1901 on 'Intrusive Tuff-like Igneous Rocks & Breccias,' a few separate papers by him are contained in the Proceedings of the Royal Irish Academy, the 'Geological Magazine' (1895), the Proceedings of the Geologists' Association (1895), and other journals. Though of strong convictions in matters geological, McHenry was endowed with a spirit of tolerance and humour which rendered any argument delightful, and made him at all times the most cheerful of comrades. Devoted to his family, kindly and affectionate in every relationship with his fellows, he went through life gently, and had the good-will of all. He died in Dublin, after a short illness, on April 19th, 1919, in his 76th year.

Some Features of the Pleistocene Glaciation of England.

Introduction.

I propose to use the present opportunity to review the changes brought about in the surface-features of our country by the Pleistocene glaciation, and incidentally to apply on a broad scale some inferences respecting the origin of these features, which have been deduced from the study of particular tracts. In what I have to tell there will be little or nothing that has not been already told somewhere or other in our voluminous Glacial literature; but I hope that a rearrangement and restatement of the scattered material in fresh perspective may be found useful.

England before Glaciation.

The delimitation of 'the Glacial Period' as a definite time-interval has always presented difficulties. Usually the term is intended to cover the whole of the cold period or periods of Pleistocene times; but in England it is more commonly used in a restricted local sense, for the time during which deposits owing their origin to the presence of ice were accumulated in any particular district, even though it be recognized that the event was not synchronous, or of equal duration, over the whole country. This 'English Glaciation Stage,' as it might be more correctly called, evidently occupied only a portion of the 'Glacial Period' in the broader sense, and I am inclined to think that it found place rather late in the period. At any rate, the longer I have studied the English drifts, the more strongly have I been impressed with the importance and complexity of the chain of events between the onset of the cold conditions and the actual glaciation. In Norfolk this interval is partly represented by the variable series of marine, estuarine, and freshwater deposits below the Cromer Till, and, more imperfectly, in East Yorkshire and a few other parts of the country by patches of Raised Beach and of Land Wash; but for the country generally it was a time of severe erosion, yielding little or no stratigraphical evidence, and marked only by the physiographical changes wrought upon the land.

During this time there was a general uplift, or emergence, by which the marginal platforms carved out around many parts of our islands during late-Tertiary times were elevated into plateaux of moderate height and were sharply dissected, while the hill-ranges beyond them were deeply incised with drainage-systems which have lasted, with minor modifications, to the present day. It is hard to say how much of the time should be reckoned as falling within the Glacial Period proper, but we have evidence that the prevalent characteristics of its climate were heavy precipitation, powerful seasonal floods, and a low winter temperature. Round the outskirts of the land, the principal valleys were graded down to considerably below present sea-level, and most of their detritus appears to have been swept far beyond our existing coast-line. Since the land-margin at this stage lay everywhere much to the seaward of its present place, it is quite inaccessible to observation, so that we cannot determine its extreme position or trace its changes. It was probably not long stable in any place; as we

know that, from Pliocene times onward, some influence was in operation which caused much instability in the sea-level. This influence is usually assigned in some form or other to the waxing of the Scandinavian ice-sheet, which may be supposed to have initiated changes by compensative readjustment of the crust, by the abstraction of water from the sea, and by the attraction of its mass; but into these matters I do not propose to enter. What we know for certain is that the stage of relative elevation was followed by a stage of relative depression, during which the seas around England were brought to a level slightly above that of to-day and remained long enough at that level to carve out a strong coastal shelf in hard rocks. Afterwards, the sea sank away again from this coast-line; and then the glacial invasion of our low ground began.

To appreciate the effect of the ensuing glaciation upon the shape of the land, let us consider how England stood when the pre-glaciation Raised Beaches were formed.

From the relation of the drift-deposits to the solid rocks we can deduce that all the main upland features were then almost as we find them to-day, notwithstanding the sharp modification in detail which they have since undergone. The hill-ranges all held their present relative values in altitude and mass; the main escarpments had reached positions not appreciably different from their present standing; the general slope of the land towards the sea-basins was as now; the trunk-drainage of the uplands, together with most of its branches, was established on lines which have passed down to us without much change; and the broad distinction between the hill-districts and the lowlands was everywhere that which we still recognize. Before the glaciation the hills as a whole were doubtless a little higher; their slopes a little more rugged in some parts and less rugged in others; and their stream-beds rather more regularly graded: but the changes in the aggregate have been relatively so unimportant that we may imagine that a pre-Glacial hill-man (granting him former existence and an eye for country) would still be able, if resurrected, to find his way about our mountains without much difficulty.

In the lowlands, however, it is quite another story. There, our ancient man would be in a new world, and completely lost. Just as the upland features are essentially pre-glaciation, so the features of the lowlands are essentially glaciation-products, either directly or indirectly.

Features due to Glaciation.

It was on the low ground that the ice-sheets abandoned most of their transported burden, with the result that in many parts a new surface was built up, with new outlines and new or nearly new drainage-systems. A considerable portion of the new country was a clear gain of land at the expense of the sea; and, in its present-day encroachment, the sea in most places is only claiming its own again. Let us examine how much of England would disappear if the drifts were to behave like their parent ice and melt out of existence. I have prepared an outline-map on a small scale (see folding-plate, facing p. lxxxii) in which the area is approximately marked out; showing also, separately, the principal extension of the drift where its base is above sea-level.

This map has been compiled mainly from the drift-editions of the 1-inch maps of the Geological Survey where available; and where these are lacking, from other published sources and from information supplied to me by several colleagues on the Geological Survey, to whom I desire to render my thanks. The small scale of the map precludes detail, and the boundary-lines are necessarily generalized, particularly those marking the inland margins of the drift-sheets. In delineating the outlines of the drift below sea-level, I have consulted the memoirs and 'horizontal sections' of the Geological Survey, together with other literature to which reference, where needful, will be given (in footnotes).

Turning to the map, we may note that the rocky coast of Northumberland and Durham is broken by several embayments and estuaries into which the sea would penetrate if the drifts were removed, while a deep drift-filled channel in the interior, connecting the River Wear with the Tyne, also descends below sea-level.[1] On the borders of Durham and Yorkshire the coast would swing inland around the present estuary of the Tees, admitting the sea into a basin 10 or 15 miles wide, with an arm running southwards towards the Vale of York. At Whitby the buried valley of the Esk would form a sharp inlet; and south of Scarborough the sea would flow up the Vale of Pickering for about 20 miles, forming a

[1] For particulars relating to this channel, and to the drifts between Tyne and Tees, see 'The Superficial Deposits & Pre-Glacial Valleys of the Northumberland & Durham Coalfield' by D. Woolacott, Q. J. G. S. vol. lxi (1905) pp. 64–96; and 'The Scandinavian Drift of the Durham Coast & the General Glaciology of South-East Durham' by C. T. Trechmann, *ibid.* vol. lxxi (1915) pp. 53–80; also other papers by the same authors.

gulf with an average breadth of 3 or 4 miles, having its outlet between Filey and Speeton. South of Flamborough Head the whole of Holderness would be under water, with creeks here and there running into the mouths of some of the Chalk valleys. The Humber would become a strait, hardly wider than at present, where it cuts through the Wolds, but giving passage to a flood which would inundate the Vale of York up to Boroughbridge, throw narrow tongues southwards up the valleys of the Ancholm and Trent, and spread out broadly between Selby and Doncaster.[1] In East Lincolnshire the conditions would be as in Holderness, with the sea everywhere up to the foot of the Wolds, and at least one deep channel leading into them. The Wash, broadened considerably on the Lincolnshire side, would be the entrance to a great bay covering the whole of the Fen country, with the exception of a few islands between March and Cambridge. East of this bay, nearly one-half of Norfolk and almost as much of Suffolk would be submerged, with an intricate system of sounds, creeks, and water-passes breaking up the remnants of the land.[2] Farther south, up to the termination of the glaciated area, the drift lies mostly above sea-level; but some of the valleys contain gravels below sea-level which appear to date back to Glacial times, and the same is the case also with the coastal valleys south of the drift-covered area. If these old gravels were removed, along with their covering of more recent alluvia, the indentations of the coast of Essex and North Kent, and the estuary of the Thames, would be considerably enlarged. Similarly, all round the south coast the clearing away of the valley-deposits, along with the Coombe Rock and Head, would admit the sea farther into most of the bays and creeks; without, however, seriously modifying the present outline of the land.[3]

[1] The underground contours of the drift in the south-western part of the Humber basin are complicated, and require further investigation.

[2] The area of drift below sea-level in Norfolk & Suffolk is shown in two maps in the Geological Survey memoir 'On the Thicknesses of Strata in the Counties of England & Wales' 1916, pp. 99 & 127. I have copied these maps with some slight modification; but, when further information is obtained from borings, it is likely that the maps will require alteration. Reference should also be made to a paper 'On the Age of the Suffolk Valleys; with Notes on the Buried Channels of Drift' by P. G. H. Boswell, Q. J. G. S. vol. lxix (1913) pp. 581–618.

[3] The areas affected along the south coast are too small and irregular to be shown on the map: particulars respecting many of the inlets are contained in a paper 'On some Submerged Rock-Valleys in South Wales, Devon, & Cornwall' by T. Codrington, Q. J. G. S. vol. liv (1898) pp. 251–76.

On the west coast we enter the region of the drift again on the north side of the Bristol Channel. Along the shores of South and Central Wales, and in Anglesey, the sea would gain limited access in many places by the removal of the Pleistocene deposits; but it is not until we reach North Wales that the shape of the land would be radically altered. Here most of the broad Vale of Clwyd would become an arm of the sea, stretching southward nearly to Ruthin; most of the Flintshire coast would be invaded; and the estuary of the Dee would be prolonged by a deep inlet, running past Wrexham nearly to the entrance to the Vale of Llangollen.[1]

In Cheshire and West Lancashire the marine invasion would be similar in many respects to that between the same latitudes in the east of England, and broadly extensive; so that the distance across the land, between tide-water and tide-water, would be reduced to 60 miles or less. A large portion of the Wirral peninsula would be submerged, together with much of the low country to the north-east and south-east, the estuary of the Mersey being prolonged far to the eastward, with narrow branches continuing into the salt-field and neighbouring tracts, and a long arm probably running southwards between Chester and Tarporley.[2]

Between the Mersey and the Ribble, and between the Ribble and the Lune, practically the whole of the West Lancashire plain would become sea, continuous with Morecambe Bay. North of this bay the changes would be comparatively insignificant, being confined to some narrow strips along the open coast,[3] together with an enlargement of the Solway Firth.

In the Isle of Man the northern plain would be wholly submerged, reducing the size of the island by about a fifth.

For the proof that the solid rock lies below sea-level in these areas we are dependent, of course, mainly upon the evidence of borings; and this evidence, while explicit in a broad sense, is rarely so full as to enable us to define the limits exactly. Upon a rough estimate, however, we may conclude that, in the aggregate, a little

[1] L. J. Wills, 'Late Glacial & Post-Glacial Changes in the Lower Dee Valley' Q. J. G. S. vol. lxviii (1912) pp. 180–97 & pl. xi.

[2] The buried valley-system of the Cheshire and Lancashire plain is complicated, and has not yet been worked out in detail. The 'Buried Valley of the Mersey' is discussed by T. Mellard Reade, Proc. Geol. Soc. Liverpool, 14th Session, 1872–73, pp. 42–65.

[3] For a recent account of the drifts of the rising ground north of the Duddon estuary, see Bernard Smith, 'The Glaciation of the Black Combe District (Cumberland)' Q. J. G. S. vol. lxviii (1912) pp. 402–48 & pls. xli–xliii.

over 5000 square miles of land in England and Wales would vanish if the Pleistocene deposits were removed, which represents about one-eleventh of the whole country.[1]

There is definite evidence that most of this area was covered temporarily by the sea shortly before the onset of the glaciation. Some part of it, however, may at that time have been above sea-level, since in certain spots the lowering of the rock-surface to its present level appears to have been effected by glacial erosion—a point to which I shall revert. It is, of course, obvious that the shape of the surface in this portion of our country is dependent entirely upon the Glacial and post-Glacial deposits.

We have next to consider the tracts, even more extensive than the last, in which the solid rocks, although above sea-level, are so deeply buried under drift that they have practically no effect upon the features, except in providing the concealed foundation. Ground of this kind fringes, more or less broadly, most of the depressions just described; and expands over wide areas in the Eastern and Midland counties, as well as in Cheshire, Lancashire, and Cumberland; prevailing chiefly, but not entirely, on the softer clayey formations which are least assertive in themselves as feature-builders. These tracts have usually rather ragged and indefinite limits where they encroach upon the strong feature-building formations; but their broad outlines are readily traceable, and are shown approximately on the map facing p. lxxxii. It will be observed that these blanketing drifts fall distinctly into two groups—an eastern and a western; and are most continuous where the seaward slopes are gradual. They mark respectively the effect of the 'East British' ice-sheet, pressing in obliquely from the North-Sea basin, and of the 'West British' ice-sheet, pressing similarly inward from the Irish-Sea basin.[2]

Ground of this description covers in the aggregate nearly 10,000 square miles in England and Wales, which is about a sixth of

[1] These estimates of area have been obtained by measuring the tracts approximately in each separate sheet of the Geological Survey 1-inch map, and summing the figures. The results are given in round numbers, so as to avoid a fallacious appearance of accuracy; the figures actually obtained were 5350 square miles in this case, and 9930 square miles in that which follows next.

[2] See 'Names for British Ice-Sheets of the Glacial Period' (letter), Geol. Mag. 1901, p. 142.

the country. This, added to the previous fraction, raises the proportion of our land shaped wholly out of the drifts to rather over a quarter.

In the rest of England and Wales within the bounds reached by the ice-sheets, the drifts play a subordinate, though still often a conspicuous, part in the landscape; of which, however, the main features are under the control of the solid rocks. We may reckon that there is about 20,000 square miles of glacially-modified country of this kind, or well over a third of the total land-area.

There remains rather over a third of England, mostly lying south of the line drawn from the head of the Bristol Channel to the estuary of the Thames, which appears to have escaped glaciation. During the Glacial Period this tract was perhaps more drastically affected by denudation and erosion than any other part of the land; but the agents were of the normal subaerial kind, and their general effect was only to accentuate the proper features of the solid rocks.

Some Drift-Features and their Origin.

With respect to the shape of the drift-covered country, it is to be noted that one of the many attractive qualities of the Glacial deposits is the infinite diversity of their outward form, so different from the regular structural features prevalent in the rocks beneath them. This diversity constantly challenges interpretation, and is generally found to be explicable by a consideration of the local circumstances associating the original features of the land with the direction of ice-movement during the glaciation. I can now only refer, of course, in general terms to the drumlins, moraines, eskers, out-wash plains, and other such features, which would require full local discussion for their elucidation. But there are some broader matters, affecting the distribution of the English drifts as a whole, which lend themselves to treatment in mass; and it is with these that I propose mainly to deal.

One of these matters is, as to the source of the great mass of material contained in the drifts. In the higher hill-regions and on some of the bordering low ground we can usually be sure, from the composition of the deposits, that the material has been almost entirely derived from the waste of the neighbouring uplands; and sometimes such streams of local detritus may be traced on the low ground for long distances. But the greater part of the big spreads of drift shown on my map have been carried by ice-sheets which

invaded the land from the sea-basins; and it becomes questionable how much of this drift was transported from the present sea-floors as a fresh contribution to the land-mass, and how much was simply picked up and redeposited within the present bounds of the land. Some proportion certainly falls under the latter category, as witness the boulders of Lake-District and Cheviot rocks in our East-Coast drifts, and the boulders from Scotland and the Lake District so plentiful in the lowlands of Lancashire, Cheshire, and the North-Western Midlands; but it is my impression that this proportion is not great, and that a large part of the matrix of the lowland boulder-clays and of the ingredients of the Glacial sands and gravels have been scooped up and carried forward from the sea-basins. In this matter we can glean little information from existing glaciers and ice-sheets, as they are mostly underlain by hard rocks, barring some quite minor tracts in Spitsbergen and the smaller Arctic islands, and in East Greenland and South Victoria Land. What happens when a wide massive ice-sheet rests upon an extensive low-lying area of soft formations can only be deduced from geological evidence. We can generally recognize what formations have gone to the making of our boulder-clay pastes: in the North-Western Midlands, Cheshire and the coastal lowland on the north—mainly Keuper Marl, with additions from Carboniferous strata; in North and East Yorkshire and Lincolnshire—mainly Keuper Marl and Lias, with additions from other Jurassic clays and a little Carboniferous; in the Eastern Counties and the eastern part of the Midlands—the Kimmeridge and Oxford Clays, Chalk and Lias, with local additions from the Keuper. It is true that all these formations occur on land, and often in proximity to the corresponding sheets of drift; but we must not forget that they certainly extend also under the present seas in the path which we know to have been taken by the invading ice, and that their submarine outcrops must in many cases be more extensive than their outcrops on land. Moreover, the thicker drift-masses of the lowlands very frequently have stratified material, or bands of local rubble and subaerial land-wash, at their base, and it is certain that there can have been no glacial planing-down of the solid floor in such places. Often, too, the derived fossils and other débris in the boulder-clays are different from those of the known outcrops: for instance, the Chalk belemnites, and black and red flints, and some of the Liassic ammonites in the Holderness

boulder-clays[1]; and the peculiar kind of Spilsby Sandstone common in the drifts of the South-Eastern Midlands. Granting that there are many parts of the land-area where it is evident that the strata have been torn up and mixed with the drift, particularly on the higher and more irregular ground: yet I think it is clear that, on the whole, the lowlands of England gained very much more than they lost from the glaciation; and that the huge mass of material represented by the drift-sheets bordering the sea-basins is largely an addition to our island from the sea-dredgings of the ice. The surface-features of these drift-sheets reflect the conditions of their accumulation, and help us to grasp the general course of events.

An essential difference between the carriage of detritus by water and by ice is that the water-borne detritus is moved persistently to lower levels for a resting-place, whereas the ice-borne material (as also the wind-borne) may be carried in mass to levels higher than its source. Though this uplift of the detritus rarely happens in the case of mountain-glaciers descending graded valleys, it has undoubtedly occurred on a large scale wherever the broad ice-sheets of Pleistocene times filled up the sea-basins and sprawled forward out of them to the bordering land. My long-held opinion that the ice-sheets received the largest part of their accretion of snow, and attained their greatest thickness, in these enclosed basins has been fortified by the observations of the later explorers in the Antarctic and Arctic regions. The conditions of growth of the shelf-ice, of the floating glacier-tongues, and of the Ross Barrier, in the Antarctic, graphically described to this Society a short time ago by Sir Douglas Mawson,[2] and by Mr. Frank Debenham,[3] bore directly upon this point. So, also in the Arctic, we learn from the beautifully-illustrated reports of the Danish explorers in North-East Greenland, Dr. J. P. Koch & A. Wegener,[4] that, besides the glaciers descending to the sea from the ice-reservoirs of the interior and becoming afloat, there are in some of the fiords, headless floating glaciers, specifically termed 'sikosak' by the

[1] See 'The Derived Cephalopoda of the Holderness Drift' by C. Thompson, Q. J. G. S. vol. lxix (1913) pp. 169–82.

[2] See 'Discussion on the Antarctic Ice-Cap & its Borders' Q. J. G. S. vol. lxxv (1919–20) Proc. pp. i–vii.

[3] 'A New Mode of Transportation by Ice, &c.' *ibid.* pp. 51–76.

[4] 'Die Glacialogischen Beobachtungen der Danmark-Expedition' and 'Features of the Geography of N.E. Greenland' Meddelelser om Grönland, vol. xlvi (1912–16) Nos. 1 & 2 [chapt. vi].

Eskimo, which have been formed on the spot simply by the fall of snow on the frozen sea.

It is acknowledged that the erosive power of moving ice will be greatest where the superincumbent mass is thickest; and the consequent differential effect is likely to have been strongly operative in the broad ice-sheets of our sea-basins moving over comparatively smooth floors of weak rocks. The thickest sheets of lowland drift were laid down where the ice from the basins thinned off towards its periphery, and where also its motion was checked by the rising slope of the ground. The existence of these rising slopes fringing the areas of glaciation in the plains is, I believe, the chief condition which has determined the extent and surface-form of our lowland drift-deposits. Where the spreading of the ice-sheet was checked through advancing upon an inclined plane, its burden of transported material became gradually concentrated in a broad marginal belt, in which a large part of the material was left as boulder-clay on the dissolution of the ice, while a smaller part was redistributed by the thaw-waters, as outwash gravels where there was free outward drainage, and as laminated clays and silts alternating with gravels where the waters were ponded in lakelets between the ice and the land. It was at one time supposed that every great ice-sheet must of necessity have had a moundy terminal moraine, and efforts were constantly made to find these limiting moraines, or alternatively to account for 'extra-morainic' drifts; but it is, I think, generally recognized now that the heaped-up terminal moraine, even in the case of glaciers of Alpine type, is only a mark of exceptionally long stability of the ice-front, and is rarely in evidence where there has been rapid retreat or advance of the glacier, while in some of the broader ice-fields now existing in Arctic regions it is absent altogether. The idea that boulder-clays are produced only as *moraine profonde* also requires modification, as it seems certain that they have sometimes, perhaps often, been formed from the decay of detritus-charged stagnant ice, in the manner suggested many years ago by J. G. Goodchild in his description of the drifts of the Eden Valley.[1]

The process was well seen in operation in Spitsbergen in 1910 by those of us who had the good fortune to participate in the excursion from the Stockholm Geological Congress. We were

[1] 'The Glacial Phenomena of the Eden Valley, &c.' Q. J. G. S. vol. xxxi (1875) pp. 55–99, and 'Ice-work in Edenside, &c.' Trans. Cumberland & Westmorland Assoc. No. 11 (1886–87) pp. 111–67.

shown how the snout of a rapidly retreating glacier, aground on an island in one of the branches of Ice Fiord, had become detached from its parent-mass and left behind in the retreat. It was being dissected by melting; and we found that the surface of the ice and the ground around it were blanketed with a thick mass of shelly clay remarkably similar to some of our English lowland boulder-clays.[1] The 'terminal moraine' in this case was a mud-belt, rather lumpy at the time of our visit, but likely soon to be reduced to a smooth plane by exposure to the weather. The conditions here on a small scale were similar to those which must have ruled on a large scale at the receding borders of our lowland ice-sheets; and, with this instance in mind, it seems reasonable to regard the broad thick belts of boulder-clay of our eastern and midland counties as a modified form of 'terminal moraine,' their deposition in such masses being a mark of the terminal enfeeblement of the invading ice.

Another point of importance bearing upon the characteristics of the Glacial deposits, which is gradually emerging from the study of existing glaciers and ice-fields, is the cumulative evidence that ice-movement is rarely, if ever, regular, but proceeds by the alternation of short periods of quick advance with longer intervals of stagnation or relative quiescence. This condition has been found now in every region where existing glaciers have been brought under observation. It is perhaps best known in respect of certain glaciers of Alaska, Spitsbergen, and the Himalaya[2]; but has been

[1] The circumstances were described to this Society on December 10th, 1910, by Sir Aubrey Strahan, in a lecture with lantern-illustrations. They are dealt with, also, in a paper 'On the Shelly Moraine of the Sefström Glacier & other Spitsbergen Phenomena illustrative of British Glacial Conditions' by G. W. Lamplugh, Proc. Yorks. Geol. Soc. vol. xvii, pt. 3 (1911) pp. 216–41; and in 'Glacial Features in Spitsbergen in relation to Irish Geology' by Prof. G. A. J. Cole, Proc. Roy. Irish Acad. vol. xxix (1911) pp. 191–208. A previous account of the glaciers and their recent changes was given by Prof. G. J. De Geer in a 'Guide' prepared for the Congress Excursion.

[2] The literature is too copious for full references, but I may cite the following as examples:—Alaska—'The Yakutat Bay Region' by R. S. Tarr & B. S. Butler, U.S. Geol. Surv. Profess. Paper 64 (1909), and 'The Earthquakes at Yakutat Bay in September, 1899' by R. S. Tarr & L. Martin, *ibid.* 69 (1912); Spitsbergen—'Guide de l'Excursion au Spitsberg' by G. J. De Geer, XIème Congrès Géol. Internat. Stockholm (1910); Himalaya—'Glacier Exploration in the Eastern Karakoram,' with appendix, 'Notes on the Glaciers of the Upper Shyok Valley' by T. G. Longstaff, Geogr. Journ. vol. xxxv (1910) pp. 622–53; also further discussion in papers by Sven Hedin and W. H. Workman, *ibid.* vol. xxxvi (1910) pp. 184–94, and 194–96.

recognized also in parts of the Antarctic; in East Greenland; and even, on a small scale, in the little glaciers of the Alps. During the quiet periods the glacier is said to be 'dead,' as its motion is so slow as to be almost imperceptible; crevasses disappear; it 'melts as it stands'; and its surface becomes littered with, and even buried under, the solid detritus which it contained. During the active intervals the ice starts forward, and is 'alive' again; and, once started, proceeds with gathered momentum, bursting onward like a slow avalanche, tearing itself into a maze of impassable crevasses, and at its termination lurching irresistibly beyond its former bounds. These revolutionary conditions were magnificently displayed in Alaska some years ago by many of the glaciers, and on the grandest scale by the Malaspina Glacier. In that region Prof. R. S. Tarr & Prof. L. Martin sought to explain the activity as the after-result of the earthquake of 1899, in shaking down avalanches of snow into the nevé-basins feeding the glaciers. But this explanation does not appear to be applicable to cases in Spitsbergen and elsewhere, which are equally striking; and, although an earthquake may be a contributory cause, it has not been proved to be essential. In Spitsbergen in 1910 we saw two glaciers which became confluent before reaching their termination in the sea in the North Branch of Ice Fiord, and one of these, the Svea Glacier, was in the 'dead' state, while the other, the Wahlenberg, was very much 'alive'. Prof. De Geer has traced the history of these irregular movements in several Spitsbergen glaciers; and, in describing them to us personally during our visit to Spitsbergen, he put forward the suggestion that they may be due to the inadequacy of the snowfall to maintain a constant flow, so that the accumulated load of several years may be required to overcome the inertia of a quiescent glacier; with the consequence that, once the movement is started, it may go on quickly until the extra load is discharged and a stage of quiescence again reached. If this should prove to be a general cause, it will apply with especial weight to glaciers and ice-sheets accumulated on flat ground, or in basins of gentle gradient; and I think that it may enable us to comprehend many peculiarities of our drifts. Particularly, it will explain the common occurrence of level tracts of boulder-clay at the surface over wide areas. I have often striven to understand how these broad surfaces could be left by a retiring glacier without any covering of fluvio-glacial material; my difficulty being that, whereas the ice in liquefying must everywhere have set free great floods of water, which should have caused

a preponderance of washed drift at the surface, yet the sands and gravels of this origin are relatively circumscribed in extent, and are mostly concentrated in mounds, ridges, or open delta-like patches. If, however, the advance of the waxing ice was spasmodic and temporarily rapid, with quiescent pauses; and if its maximum extension was reached by a final forward spurt, which may have happened at different times in different places, the conditions for producing the sheets of bare boulder-clay, as well as the irregular features of the sands and gravels, can be readily grasped. Around its periphery the ice, after its latest spurt, sank into the 'dead' condition and never again revived, for meantime the ameliorating circumstances which marked the close of the Glacial Period had become effective. Where the ice before its relapse had surmounted the low watersheds of its principal basins, so that the bare land in front of it had a downward slope, as for example in the catchment areas of some of the northern tributaries of the Thames and of the Severn, the copious thaw-water escaped for a time outward, spreading its burden of solid waste in great masses beyond the invaded area.[1] But, where the ice came finally to rest on rising ground, or where at any time during its waning it was brought into this position by shrinkage, the drainage during the thaw would be in the main backward, on or under the ice, and would be unable to transport any material outward on to the bare land. In this manner the clays contained in the dissolving fringe of the ice-sheet, along with those underlying it, would remain comparatively unaffected, and would settle quietly down to their permanent resting-place. The drainage conditions in many places would, in fact, be similar to those which we saw around the detached end of the Sefström Glacier in Spitsbergen, where a thick mass of ice-transported clay was being left at the surface with hardly a trace of stream-borne material upon it, and only very little at its margin.

It is, of course, certain that in some places the presence of boulder-clay at the existing surface is due to the sweeping-away of its cover by post-Glacial denudation; but I believe that all the broader plateau-like spreads of our lowlands are original features, produced more or less in the manner described.

Besides the areas shown on my map, where the drifts are con-

[1] For a recent summary and discussion of the evidence around the south-western fringe of the Midland area of glaciation, with good bibliography, see 'Notes on the Cotteswold-Malvern Region during the Quaternary Period' by J. W. Gray, Proc. Cotteswold Nat. F. C. vol. xx, pt. 2 (1919) pp. 99–141.

tinuous and are responsible for practically all the features, there are still wider areas, uncoloured on the map, in which there is a mingling of solid outcrops and patches of drift. This condition prevails over the greater part of the North Midland counties and much of the South Midlands; and in such country it is often difficult to decide in what degree the shape of the land has been modified by the glaciation. Generally there is evidence of very severe erosion since the drifts were deposited; and most of the present features appear to be due to this erosion. The patches of drift occur sometimes amid areas of bare rock which might otherwise have been supposed to lie beyond the limits of glaciation. The question constantly arises whether these patches are the remnants of a once-continuous sheet, perhaps representing an older glaciation than that which left the thick cover in our eastern and north-western counties, or whether they were scanty and discontinuous from the first. That their dimensions have been considerably reduced is often evident; but in their composition and mode of occurrence they frequently carry indications of original limitation and local incidence. Particularly is this the case with the sporadic mounds and ridges of sand and gravel, that occur in numerous places at relatively high elevations and are shaped in a manner inexplicable except as indicative of local accumulation. The isolated patches of boulder-clay, also, are found mostly in hollows or sheltered places amid the 'solid' outcrops, where it is conceivable that the material may have been trapped, while the main unimpeded ice-flow carried the rest of its burden forward to its periphery. I should like to have discussed some specific instances of this type which have come under my notice, but find it impossible to do so within the scope of this address. I must content myself, therefore, with the general statement of my opinion that, in most places, where the drift is patchy now in the Midlands, it was always patchy, and is not the remnants of a once-continuous covering. It is, in fact, more remarkable that the ice should anywhere have left such extensive sheets of drift as those of the East of England, than that it should have passed over some of the country without leaving much trace of its passage. In almost all areas of present-day glaciation it is a matter of common occurrence to find bare rocky tracts, known to have been covered by ice not long ago, on which there is nothing except an occasional erratic to mark the event.

In the Central Midlands there can have been little 'back-

drainage' of the thaw-water; and the erosion of the land outside the receding ice-margin was consequently severe, and was accompanied by the deposition of much fluvio-glacial material. As a result, the drainage-system of the whole area has been greatly changed, particularly in respect of the main water-partings traversing the lowland. It is known that the courses of the Dee, Severn, Trent, and Upper Thames, have all been strongly affected; but much work remains to be done before the whole history of these changes can be attempted. Indications of temporary lakes are abundant; and the main channels of discharge must have shifted their position widely as the ice-barriers on the north-west and north-east sank gradually away.

When mapping tracts in the North-Eastern Midlands in the course of my official work on the Geological Survey, I have repeatedly met with features in driftless, or nearly driftless ground, for which I could find no explanation in the 'solid' structure, or in the present drainage-system. I have in mind particularly some instances of small escarpment-like banks or ridges at the borders of flats practically bare of drift, which closely simulate rock-features, yet bear no relation to the rock-structure. Such features may in most cases be assigned with probability to the exceptional action of Glacial flood-waters, forced temporarily into irregular and aberrant courses.

In the same region another problem presents itself, in the occasional abrupt ending of thick boulder-clay in steep banks overlooking ground devoid of drift. The most striking example of this kind known to me is the high bank which terminates the bare tract of Lias in the Vale of Belvoir, and rises westwards to the broad upland spur of boulder-clay known as the Nottinghamshire Wolds, where the drift is in places over 100 feet thick. In appearance and structure the bank presents the essentials of an escarpment, and seems, therefore, to denote the wearing-back and the possibly extensive reduction of the original plateau of boulder-clay. But I think that the appearance is deceptive in this, as in other cases of the same kind which have come under my notice, and that the main outline of the bank is due to the original concentration of the Glacial deposits in this form, though later denudation has played some subordinate part in the final shaping of the feature.

Any marginal lowland area sloping away from the ice, and bare at an early stage of the melting, must, of course, have undergone swift erosion, seeing that it had to carry off much extraneous thaw-

water in addition to its own local precipitation: the latter at that time probably all pent up as snow during the winter, and released suddenly in the spring to augment the floods from the ice-sheet. Therefore it is not surprising that the glaciation-features of such areas have acquired a more mature and subdued aspect than the corresponding features of the country sloping to the sea-basins, uncovered later and never inundated in the same way by thaw-water. But I do not think that this difference of aspect in the case of the English drifts implies more than a comparatively unimportant difference in time, or that there is room or evidence for an interglacial period, as is sometimes supposed, between the inner and the outer drifts.

The Hill-Drifts.

There remains to be considered the effect of the glaciation upon the hills. As I have mentioned already, this effect has been comparatively slight so far as the main features are concerned; nevertheless, in the detail almost everywhere much new shaping has been done, and the old shapes modified. The work of Prof. P. F. Kendall in the Cleveland Hills some years ago called attention to the peculiar and characteristic erosion-forms produced by the damming and diversion of the drainage in country just outside the margin of the ice-sheet; and many observers have since found that similar phenomena are recognizable in the hill-regions all over England and Wales, as well as in Scotland and Ireland, wherever ice-sheets or glaciers have blocked the pre-existing slopes and channels of discharge. These new features are particularly prevalent on the outer slopes of the hill-masses; and they generally indicate that the high ground, if ever covered, became free from ice long before the plains were uncovered. The 'overflow channels,' 'dry gaps,' 'delta-fans,' 'corroms,' and other phenomena due to these conditions have, at this day, been so frequently described that I need but mention them to recall how material in the aggregate is their influence on our hill-scenery, of which they not rarely provide the most picturesque incidents.

These effects we may regard as interlinked with, and dependent upon, the glaciation of the lowlands. But to the hills more peculiarly belongs another group of phenomena, so conspicuous in aspect and so convincing as to origin, that it was the first to secure attention in the early days of our science, and to obtain recognition as proof of the existence of ancient glaciers in Britain. I refer,

of course, to the morainic mounds in the valleys; the roches moutonnées; the transported blocks; the tarns and lake-basins; and the cwms and corries. The association of these phenomena in the broader valleys was so clearly analogous to the phenomena associated with the valley-glaciers of the Alps, the only form of land-ice studied at close quarters in those days, that the idea of the mountain-glacier became rooted as the essential explanation of all our drifts; and it has often hampered the interpretation of the very different conditions governing the widespread glaciation of the plains. However, so far as the mountain-valleys are concerned, we can generally trace in their minor features all the usual results of the passage, of glaciers down them; and, even while most of the valleys themselves are older than the glaciation, their present outlines owe much to the influence of the ice. Their shape has been altered, in one way by the rasping-down of the solid rocks, and in another way by the deposition of transported material in thick masses within them, by which the actual water-channel has been frequently deflected from its former position, and the stream forced to carve out a second channel in the rock, beginning much above the level of its previous floor. In almost every upland valley within the glaciated area this deflection of the river-course is in evidence somewhere or other, and has been studied and described in so many instances that particularized citation is unnecessary.

On the high ground between the valleys, where this came also within the sweep of the ice, the features have probably undergone less change than in any other part of our country, the chief effect of the glaciation having been to clear away all the loose detritus from exposed positions, redepositing some of it at high levels on sheltered flats and hollows of the uplands, but conveying the larger portion away from the hills altogether, so that it became mingled with the drift of the plains.

And here I may remark parenthetically upon a noteworthy circumstance connected with the drifts derived from the land-area in England. It is the great rarity of relics of pre-existing life, either vegetable or animal, in the boulder-clays and rubble-drifts, notwithstanding that they must include whatever loose material lay on the old land-surface. That boulder-clay is a fairly good vehicle for carrying and preserving such relics, is proved by the common occurrence of marine shells, even in the state of small fragments, in all the drifts derived from the old sea-floors. Also, boulder-clay is not like the fine-grained stratified sediments in which the original

material has all been milled down to a minute state of subdivision before being redeposited; it commonly contains recognizable shreds and fragments, both large and small, of the pre-existing beds which have gone to the making of it. If our uplands had been covered, before the glaciation, with hill-peat to anything approaching the present extent, and if our lowlands had then exhibited the mixture of forest-growth and swamp which we know to have been a prevalent condition at the beginning of historic times, we ought to find abundant traces of this ancient land-covering among the material gathered together by the ice in its passage over the surface. Loose fragments of wood are widely distributed in the tills of some parts of the northern interior of the United States,[1] presumably betokening the destruction by ice of a forested tract, recalling the course of events in Alaska early in the present century, when the 'dead ice' of the Malaspina and other glaciers suddenly became 'alive' and spurted forward.[2] But in the British boulder-clays or tills of land-derivation, relics of land-life, other than an extremely rare fragment of bone or tooth of a big animal, are most exceptional. Personally, although I have searched long and carefully in many parts of the country, all I have found are two or three shreds of peaty material in the lowest boulder-clay of the Yorkshire coast; probably derived from some pre-existing deposit, as they were associated with shreds of marine deposits also.[3] Lately, Dr. C. T. Trechmann[4] has described the occurrence of some relics of the same kind at the base of the drift on the Durham coast. In Scotland, wisps and patches of peaty stuff in boulder-clay have been noted in three or four places only.[5] In Ireland, despite the large tracts of inland drift, I know of no case where the boulder-clay has yielded remains of the old land-life.

It seems hardly possible that there would have been this extreme scantiness of organic terrestrial relics in the boulder-clay if the advancing glaciers had impinged upon a forested country; and other factors also point to a barren, timberless, storm-swept state of the land for some time prior to the glaciation. It is indeed likely

[1] See Frank Leverett, 'The Glacial Formations & Drainage Features of the Erie & Ohio Basins' U.S. Geol. Surv. Monogr. xli (1902) p. 273 & pl. xiv.

[2] See Alaska references cited previously, p. lxxii.

[3] Q. J. G. S. vol. xl (1884) pp. 313–15; and another example, unrecorded.

[4] Q. J. G. S. vol. lxxi (1915) p. 57; and vol. lxxv (1919–20) pp. 181–84.

[5] For references and critical notes, see 'The Origin of the British Flora' by Clement Reid, F.R.S. London, 1889.

that this state would be brought about by the outrush of cold air resulting from the proximity and gradual approach of the Scandinavian ice-sheet, since we know that this is the effect of existing ice-sheets in Greenland and the Antarctic. Yet, on the other hand, the remains of huge herbivorous mammals, such as the elephant, hippopotamus, and rhinoceros, are found plentifully in many places in old beaches, cave-deposits, etc., immediately beneath boulder-clay, as well as in ancient river-gravels and other terrestrial deposits apparently dating at different times between the beginning and the end of the glaciation; which seems to afford proof that there must have been abundant vegetation of some kind in the country during the period. It may be that the valleys and lowlands, where ice-free, carried a seasonal cover of perishable grass and small shrubs, like the tundra and prairies of the present day, though without the massed growth and continuous moisture required to produce peat. But now, I must be content with having stated the problem as it presents itself to me, leaving it to you for consideration.

To return to my main subject; we can recognize that the principal effects of the glaciation upon the uplands has been to increase the area of bare rock; to subdue some of the sharper features; and to accentuate some of the minor escarpments by removing the products of weathering with which they were encumbered. The general lowering of the surface has probably been less on the ice-covered hills than it would have been if they had been continuously exposed to the direct attack of subaerial weathering; for it must be remembered that a thin capping of ice or nevé not in active motion will serve as a protection to the platform beneath it.

In the final shaping of the hills the selective course and localized incidence of the glaciation, particularly in the waning stages, must have been a pronounced factor. The more we learn about the regional ice-sheets of the present day, the more evident does it become that the old idea of smooth ice-caps of regular gradient, flowing evenly over the land and filling up all the hollows to a general level, is inaccurate in many respects. The striking fact has emerged, that ice-free valleys and lowlands may occur in unexpected places, sometimes insulated, but more often deeply indenting the borders of the land-ice. Such tracts may be dominated by great stretches of moving ice, which carry the discharge of the main ice-cap along definite paths; and, if a valley or lowland lie aside from the path, and cannot nourish a glacier of its own, it may remain as

bare land amid mountains of ice. The recent investigation of North-East Greenland has revealed some remarkable instances of this kind; others are known in Grinnel Land, Ellesmere Land, and the neighbouring archipelago [1]; Spitsbergen affords abundant illustrations; and even in Antarctica some low-lying ice-free tracts have been observed. The possibility of this great inequality of condition in contiguous tracts of similar altitude and structure is a strong distinction between glacial action and the effects of atmospheric weathering, or of submergence beneath water, both of which bring about comparative equality of circumstance throughout the tract at any particular level. Of prime consequence on the plains, this 'localization of effect' has undoubtedly left its mark also on the hill-regions, where some tracts have evidently been thoroughly scoured by the glaciation, while others, close by, have been hardly touched. The tracing-out of these varying effects in detail on the high ground still affords an interesting and comparatively unworked field for the interpretive glacialist.

Post-Glacial Features.

Though so much of our country is shaped, as we have seen, by the drifts, we must take into account that the finishing touches to the features have been wrought by the agencies in operation during post-Glacial and recent times. In the new-made land, as for example, Holderness and West Lancashire, the drainage-system is entirely post-Glacial; as it is also in most of the thickly drift-covered country of the Eastern counties, the Cheshire and Flintshire lowland, and Wirral; and these areas afford an opportunity for gauging roughly the time that has elapsed since the glaciation by the amount of erosive work performed in it. Indeed, there is some hope that intensive study of this erosion, and of the small drift-basins infilled with freshwater deposits, may eventually yield numerical data for the time-interval, analogous to those which have been obtained in Sweden from the researches of our esteemed Wollaston Medallist, Prof. G. J. De Geer, whose work we have honoured to-day. It is very notable, however, in these areas how much the present aspect of the drift depends upon the drainage-slope; in tracts of sluggish or clogged drainage the glacial

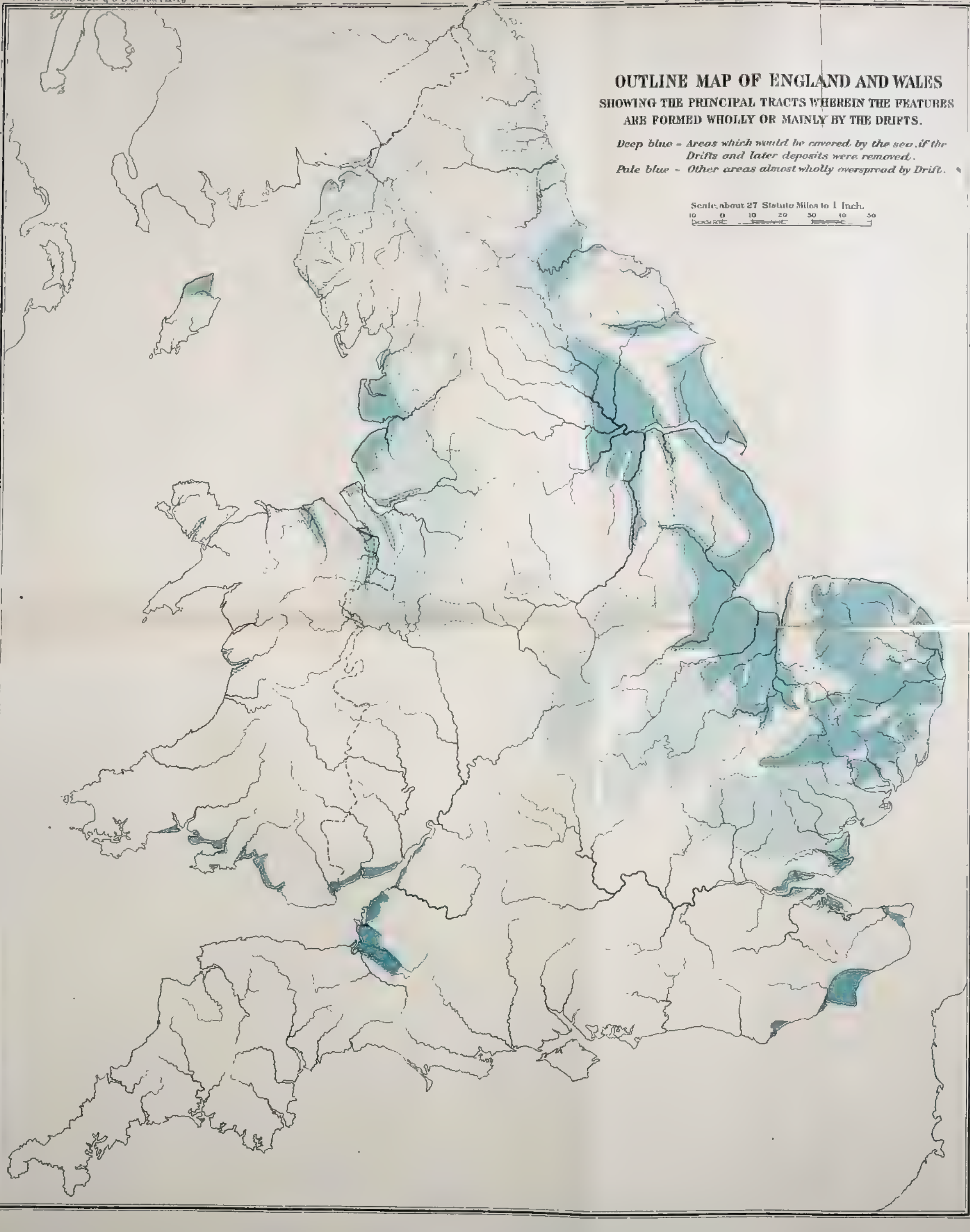
[1] For a useful and well-illustrated review of the conditions in Arctic lands, with copious references to literature, see W. H. Hobbs, 'Characteristics of the Inland Ice of the Arctic Regions' Proc. Amer. Phil. Soc. vol. xlix (1910) pp. 57–129 & pls. xxvi–xxx.

gravel-mounds and banks or drumlins of boulder-clay have retained what we must suppose to be their original features almost unimpaired; whereas the continuations of the same tracts, on reaching a position of free and sharp drainage, break down at once into dissected ground which gives the impression of comparatively long-endured erosion. In fact, the Glacial deposits are, as a whole, so susceptible to weathering and stream-action that their aspect at any place is a measure of the violence of the attack rather than of its length; and deductions drawn from their relative condition in this respect may be very misleading. It has nevertheless been ascertained, from the study of the post-Glacial freshwater deposits and other phenomena, that there have been rather wide vicissitudes of climate and of sea-level since the disappearance of the ice. We know also that the event is sufficiently remote to have allowed time for practically all the larger valleys of the later drainage to have been cut down to base-level, or nearly so, wherever they cross the lowland drift-covered tracts; which in itself implies considerable local reshaping of the ground.

In the areas of scanty drift, the results of post-Glacial erosion are practically a continuation of, and hardly separable from, the earlier work of the glacial flood-waters. The Late Glacial flood-gravels and outwash-fans in many of the valleys are so copious that, in most tracts of low gradient, the shrunken rivers of subsequent times have been unable to cut through them, and the present streams meander over the old flood-plains in slightly-incised channels, the valleys being now actually shallower than they were at the close of the glaciation. This condition is exemplified, in varying degree, in all parts of the country; and widely, by the upper Trent and its tributaries; by that portion of the upper Severn which traverses the Shropshire plain; and by some of the rivers of the Vale of York.

Another obvious change in the surface-features since the drifts were deposited is due to the obliteration of most of the pools and lakelets, with which every drift-covered lowland appears to have been thickly dotted upon the melting-away of the ice. In some cases the hollows have been filled up with sediments; in others they have been drained by the opening of water-channels, often with human aid. The sediments within them are invariably of land or freshwater origin: they prove that the sea has had no part in the final shaping of the interior of our country, though it has meantime done much work on the coast-line, both by erosion and

[To face p. lxxxii.


OUTLINE MAP OF ENGLAND AND WALES
SHOWING THE PRINCIPAL TRACTS WHEREIN THE FEATURES ARE FORMED WHOLLY OR MAINLY BY THE DRIFTS.
Deep blue = Areas which would be covered by the sea, if the Drifts and later deposits were removed.
Pale blue = Other areas almost wholly overspread by Drift.
Scale, about 27 Statute Miles to 1 Inch.
10 0 10 20 30 40 50

by the accumulation of beach and estuarine deposits at the lowest levels in the creeks and bays.

In the aggregate these minor changes of late date are considerable; but they do not materially affect the proportional importance of Glacial events in modelling the land-surface as we know it. From the human standpoint, the economic consequence of these events, particularly in respect to agriculture, has been perhaps of even more importance than their physical consequence; and I believe that a study of the Racial History of the associated Drift-lands as a distinctive region would yield some interesting results. At any rate, the old Saxon and Danish invaders seem to have found these lands particularly attractive and home-like.

Here I must leave my subject, aware that my treatment of it has been desultory and unavoidably sketchy; but, if I have succeeded in bringing before you the broad general effects of the ice-sheets and their concomitants in the shaping of Our Land, my aim will have been achieved.

Now I have reached the end of my duty as your President, a duty which I shall ever recall with gratification. The two years past have been so tremendous in events, that we have found it difficult at times to bring our thoughts to bear upon the placid studies for which we are associated. Just at the beginning of my term our young men at the Front were resolutely enduring the fiercest blast of the War Storm; and our hearts were with them. Gradually there came relief; and then the swift course to victory. The troublous days of reckoning are not yet ended, but I count myself fortunate indeed that my tenure of office should have embraced the coming of Peace, and that its termination should be under happier auspices than its beginning.

Before quitting the Chair, I desire to offer my thanks to the Council for its constant support; to my fellow-officers for their indispensable aid and advice; to the permanent staff for their assistance at all times; and to the Fellows of the Society for their tolerance of my shortcomings. Under the changing conditions of our days, the affairs of the Society will need skilful guidance; and in electing my successor you have chosen one who, by his long experience and keen interest in all that pertains to the Society, is excellently qualified for the responsibility. I am sure that our welfare and progress will be safeguarded under the rule of Mr. R. D. Oldham.

February 25th, 1920.

Mr. R. D. Oldham, F.R.S., President,
in the Chair.

Thomas Arthur Acton, F.S.A., The Chalet, Minera, Wrexham (North Wales); John Challinor, Assistant Lecturer in Geology at the University College of Wales, Pickwood, Leek (Staffordshire); and Herbert William Ricketts, Deputy Curator in the Sunderland Museum & Art Gallery, 5 Lonsdale Road, Roker, Sunderland, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communication was read:—

'The Lower Carboniferous Chert-Formations of Derbyshire.' By Henry Crunden Sargent, F.G.S.[1]

Mr. H. C. Sargent exhibited rock-specimens and microscopic slides in illustration of his paper.

March 10th, 1920.

Mr. R. D. Oldham, F.R.S., President,
in the Chair.

Frederick William Allison, The Square, Guisborough (Yorkshire); Evan Hughes, Trevillett, Tintagel (Cornwall); William Thomas Lane, Assistant Lecturer in Geology in the School of Mines at Treforest, Pendeen House, Dyfodwg Street, Trevorchy, Rhondda (Glamorgan); Athanas Sotiriou, c/o Constantin Sotiriou, Banque Nationale, Athens (Greece); Harold Joseph Wheaton, Winster, Walton New Road, Lower Walton, Warrington; Robert Powley Wild, Ariel Lodge, Hewlett Road, Cheltenham; and Major Gerrard W. Williams, D.S.O., M.C., B.A., 30 Acacia Road, St. John's Wood, N.W. 8, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communication was read:—

'The Lower Palæozoic Rocks of the Arthog-Dolgelley District (Merionethshire).' By Prof. Arthur Hubert Cox, M.Sc., Ph.D., F.G.S., and Alfred Kingsley Wells, B.Sc., F.G.S.

[1] Withdrawn by permission of the Council.

Rock-specimens, fossils, microscope-slides, and lantern-slides were exhibited in illustration of their paper by Prof. A. H. Cox and Mr. A. K. Wells.

March 24th, 1920.

Mr. R. D. Oldham, F.R.S., President, in the Chair.

Brinley Clifford George, B.Sc., Lecturer in Geology & Mineralogy at the Swansea Technical College, 11 Nicholl Street, Swansea; and Frank William White, The Anchorage, Dover Street, Hull, were elected Fellows of the Society.

The List of Donations to the Library was read.

The President then said:—

'With sorrow I have to announce to the Society the loss of an old, and one of its most distinguished, Fellows—Charles Lapworth. Overcoming in his early days difficulties which would have daunted any but one of the most elect of the earth, he has added to our knowledge a wealth of observation and a number of those vitalizing concepts on which the life and progress of Science depend, and has added lustre to our Science and Society, not in this country alone, but in every land where Geology is cultivated. Your Council has already put on record its appreciation of the services which our late Fellow has rendered and sympathy with his family in their bereavement; but, considering that the Society at large would desire an opportunity of associating itself with these sentiments, I will ask your concurrence.'

The communication was received by the Fellows present, standing, and unanimously approved.

The President read a communication from the Foreign Secretary, Sir Archibald Geikie, O.M., K.C.B., F.R.S., conveying information as to the present location and conditions of life of Russian geologists, some well known in this country.

The President announced that the Council had awarded the Proceeds of the Daniel-Pidgeon Fund available in the present year to Miss Marjorie Elizabeth Jane Chandler, who proposes to investigate the Oligocene Flora of the Hordle Cliffs (Hampshire); and to Laurence Dudley Stamp, B.Sc., Assoc.K.C.L., F.G.S., who proposes to make a comparative study of the Downtonian and Gedinnian in North-Western Europe.

The following communications were read:—

1. 'On Two Preglacial Floras from Castle Eden (County Durham).' By Mrs. Eleanor M. Reid, B.Sc., F.L.S., F.G.S.

2. 'A Comparative Review of Pliocene Floras, based on the Study of Fossil Seeds.' By Mrs. Eleanor M. Reid, B.Sc., F.L.S., F.G.S.

Portions of an atlas vertebra of a big Elephant, probably near *Elephas meridionalis*, from the Pliocene of County Durham, were exhibited on behalf of Dr. C. T. Trechmann, F.G.S.

Lantern-slides of fossil seeds, etc. were exhibited by Mrs. E. M. Reid, in illustration of her papers.

April 21st, 1920.

Mr. R. D. Oldham, F.R.S., President,
in the Chair.

The List of Donations to the Library was read.

The following communications were read:—

1. 'The Devonian of Ferques (Lower Boulonnais).' By John William Dudley Robinson, B.Sc., F.G.S.

2. 'The Cambrian Horizons of Comley (Shropshire), and their Brachiopoda, Pteropoda, Gasteropoda, etc.' By Edgar Sterling Cobbold, F.G.S. (Read by Dr. H. Lapworth, M.Inst.C.E., Sec.G.S.)

Lantern-slides and rock-specimens were exhibited by Mr. J. W. Dudley Robinson, in illustration of his paper.

Diagrams and drawings of fossils were exhibited on behalf of Mr. E. S. Cobbold, in illustration of his paper.

A specimen copy of 'Mineralogical Abstracts' was exhibited on behalf of the Mineralogical Society.

May 5th, 1920.

Mr. G. W. Lamplugh, F.R.S., Vice-President,
in the Chair.

Leonard William Berry, B.A., Bradford, near Taunton (Somerset); George Rudd Collinson, B.Sc., Assoc.M.Inst.C.E., Manager of the Swansea Corporation Waterworks, Guildhall, Swansea; Alfred Charles Gardner, M.Inst.C.E., M.I.Mech.E., Great Central Railway, Healing (Lincolnshire); Trevor Starkey, Nelson (British Columbia); and Ernest Arthur Turner, 79 Trinity Road, Wimbledon, S.W. 19, were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communication was read:—

'A Natural "Eolith" Factory beneath the Thanet Sand.' By Samuel Hazzledine Warren, F.G.S.

Flaked flints were exhibited, in illustration of Mr. S. Hazzledine Warren's paper, by Mr. F. N. Haward, Mr. C. Carus-Wilson, and the Author.

May 19th, 1920.

Mr. R. D. Oldham, F.R.S., President, in the Chair.

Charles Edward Best, 11 Blenheim Gardens, N.W. 2; and Brooke Hodgson, Catamarca 1371, Pueblo General Paz, Córdoba (Argentine Republic) were elected Fellows of the Society.

The List of Donations to the Library was read.

The following communication was read:—

'On Certain Xenolithic Tertiary Minor Intrusions in the Island of Mull (Argyllshire).' By Herbert Henry Thomas, M.A., Sc.D., Sec.G.S., with chemical analyses by Ernest George Radley.

Specimens and microscope-slides in illustration of his paper were exhibited by Dr. H. H. Thomas.

A model of *Diplodocus*, presented to the Society by the Rev H. N. Hutchinson, M.A., F.G.S., was also exhibited.

June 9th, 1920.

Mr. R. D. Oldham, F.R.S., President, in the Chair.

The List of Donations to the Library was read.

The President said that, during the War, when the ordinary supply of papers for reading and discussion fell short, a series of lectures by workers on subjects cognate with geology had been instituted to fill the gap. These had been so well received and appreciated that it was hoped to continue the practice, and to devote at least one meeting in each session to this purpose. The subject of that afternoon's lecture came so far within the

scope of the objects for which the Society was established that it threw considerable light, at any rate, on the structure of the Earth. Dr. Knott had worked out a method of mathematical discussion of the long-distance records of earthquakes by which it was possible to calculate the form of the wave-paths along which the disturbance had been propagated, without recourse to the approximations and assumptions previously needed, and from these calculations it was possible to deduce conclusions of great interest regarding the constitution and structure of the Earth.

Mr. Cargill Gilston Knott, D.Sc., LL.D., F.R.S., then proceeded to deliver a Lecture on Earthquake Waves and the Elasticity of the Earth. The Lecturer remarked that the record produced on delicate seismographs of the earth-movements due to distant earthquakes proves that an earthquake is the source of two types of wave-motion which pass through the body of the Earth, and a third type which passes round the surface of the Earth. Before earthquake records were obtained, mathematicians had shown that these three types of wave-motion existed in and over a sphere consisting of elastic solid material. Many volcanic phenomena, however, suggest the quite different conception of a molten interior underlying the solid crust. At first statement these views seem to be antagonistic; but there is no difficulty in reconciling them. Whatever be the nature of the material lying immediately below the accessible crust, it must become at a certain depth a highly-heated fairly-homogeneous substance behaving like an elastic solid, with two kinds of elasticity giving rise to what are called the compressional and the distortional waves. The velocities of these waves are markedly different, being at every depth nearly in the ratio of 1·8 to 1. Both increase steadily within the first 1000 miles of descent towards the Earth's centre, the compressional wave-velocity ranging from 4·5 miles per second at the surface to 8 miles per second at depths of 1000 miles and more; the corresponding velocities of the distortional wave are 2·5 and 4·3 at the surface and at the 1000-mile depth respectively. At greater depths these high velocities seem to fall off slightly; but the records fail to give us clear information as to velocities at depths greater than about 2500 miles. Down to this depth the Earth behaves towards these waves as a highly-elastic solid. The elastic constants, which at first increase with depth more rapidly than the density, become proportional to the density, for the velocity of propagation becomes practically steady. About half-way down, however, the material seems to lose its rigidity (in the elastic sense of the term), and viscosity possibly takes its place, so that the distortional wave is killed out. In other words, there is a nucleus of about 1600 miles radius which cannot transmit distortional waves. This nucleus is enclosed by a shell of highly-elastic material transmitting both compressional and distortional waves exactly like an elastic solid.

In conveying to the Lecturer the thanks of the Meeting for his illuminating discourse, the PRESIDENT said that, although these lectures were not open for discussion as in the case of an ordinary paper, he might be permitted to express a personal feeling of gratification that his own pioneer efforts in the same line had been confirmed by the Lecturer's fuller discussion, not merely in kind, but to an unexpected degree as concerned numerical estimates. The most important result of the investigations which had been described appeared to be the discovery of the remarkable reversal in curvature of the wave-paths at a depth of about 1000 miles. It might be a mere coincidence that this was also the depth of separation, according to one well-known hypothesis, between the metallic nucleus and the stony shell of the Earth, but the coincidence was at least suggestive, and the discovery was entirely due to the Lecturer, having been unknown before it was brought out by the ingenious and exact methods of discussion which had been elaborated by him.

A geological hammer that had belonged to the late Sir Charles Lyell, and had been presented to the Society by Capt. Francis H. Lyell (his nephew), was exhibited.

A plaster bust of the late Dr. Hugh Falconer (Foreign Secretary 1863–64), presented, on behalf of Miss Milne, by Mr. W. J. Lewis Abbott, F.G.S., was also exhibited.

June 23rd, 1920.

Mr. R. D. OLDHAM, F.R.S., President, in the Chair.

Herbert Carlyle Billington, 5 Wellington Road, Higher Crumpsall, Manchester; William Alden Brown, Riverside, Marden (Kent); James Norman Carruthers, Glencoe, Leyton Avenue, Mansfield; Norman Cave-Brown-Cave, Stanmore House, Moffat (Dumfriesshire); Samuel Ernest Loxton, F.R.A.S., Icknield, Little Aston, near Sutton Coldfield (Staffordshire); Mungo Park, A.R.S.M., Assoc.Inst.M.M., Vimy Estate, Kundang, Selangor (Federated Malay States); Frank Petch, B.Sc, 6 Trentham Street, Dewsbury Road, Leeds; Henry Pooley, B.Sc., Assoc.M.Inst.C.E., 10 Gray's Inn Square, Gray's Inn, W.C. 1; Percival Ross, 41 Mannville Terrace, Morley Street, Bradford; and Ethel Mary Reader Shakespear, D.B.E., D.Sc., 21 Woodland Road, Northfield, Birmingham, were elected Fellows of the Society.

The List of Donations to the Library was read.

The Names of certain Fellows of the Society were read out for the first time, in conformity with the Bye Laws, Sect. VI. Art. 5,

in consequence of the Non-Payment of the Arrears of their Annual Contributions.

The President then said:—

'I have to announce that the Council have, with regret, decided that it will not be possible to continue the free issue of all publications to the Fellows. The great increase in the cost of all charges connected with publications makes it necessary, either to secure a considerable increase of income, or to submit to a very material reduction of publication. Believing that the latter course would be the least acceptable to the Society, the possible means of effecting the former were examined, and of them the most suitable appeared to be that of putting a price on the Journal to those Fellows who wished to receive it. No change in the present practice will be made during the current year, but from January 1st next the Quarterly Journal will only be distributed regularly to those Fellows who pay a subscription of Ten Shillings for the regular issue of four numbers; those who do not desire the complete series will be able to obtain the particular numbers in which they are interested at the price of Three Shillings per number if applied for within a year of publication, and thereafter at the price fixed for Fellows. As a partial set-off to the cessation of free distribution of the Journal, the Abstracts of Proceedings will, from the commencement of next Session, be despatched regularly to all Fellows instead of only to those resident in the United Kingdom.

'The adoption of these measures will, by the combined effect of receipts for publications distributed and savings on those not distributed, enable the work of the Society to be carried on without any large reduction in the issue of original contributions to Geology. They appear to the Council to be preferable to a permanent increase in the Annual Contributions of Fellows, from the ease with which the charge can be altered and abolished when the financial position enables this to be accomplished.'

The following communication was read:—

'The Scandinavian Mountain Problem.' By Olaf Holtedahl. (Communicated by Sir Archibald Geikie, O.M., K.C.B., F.R.S., For.Sec.G.S.)

THE

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FOR 1920.

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1. GEOLOGICAL SECTIONS *through the* ANDES *of* PERU *and* BOLIVIA: II—*From the* PORT *of* MOLLENDO *to the* INAMBARI RIVER. By JAMES ARCHIBALD DOUGLAS, M.A., B.Sc., F.G.S. (Read February 4th, 1920.)

[PLATES I–VI.]

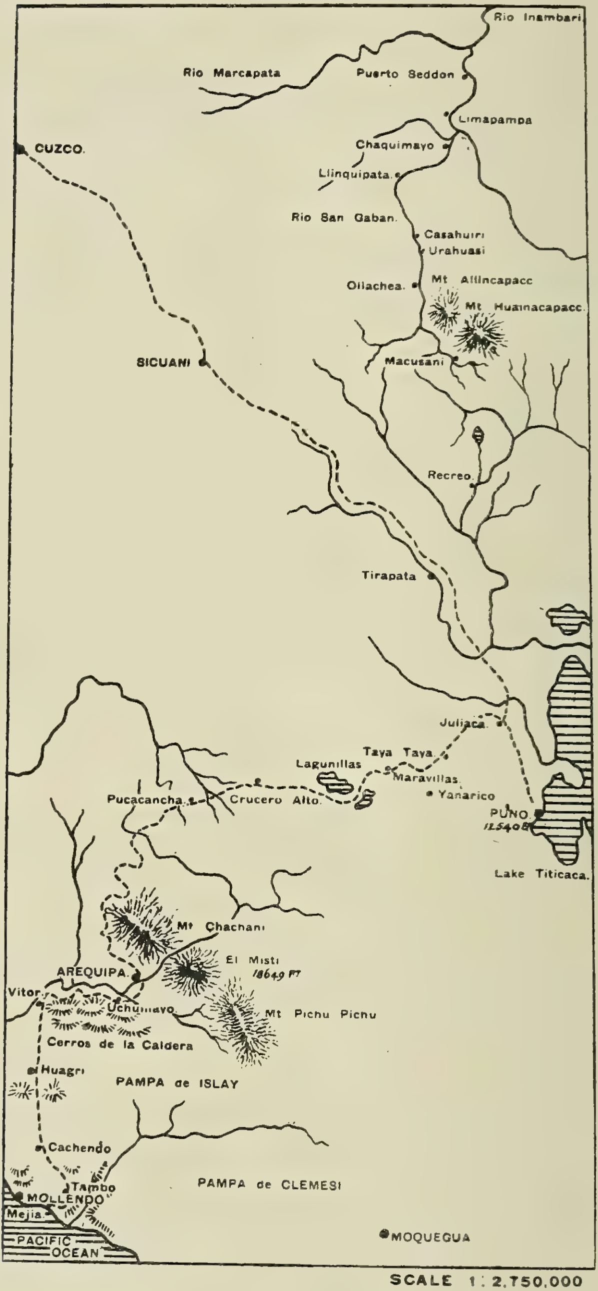
CONTENTS.

I. INTRODUCTION.

IN a former communication to this Society, published in April 1914, I described a geological section through the South American Andes, from Arica on the Pacific coast of Northern Chile to the Bolivian Yungas.

The present paper, the publication of which has been long delayed owing to the War, is a further contribution to the same series, the

Fig. 1.—*Sketch-map of the district between Mollendo and the Inambari River.*



result of work undertaken on the Balston Expedition to Peru. It deals with a second and parallel section drawn through the south of Peru from the port of Mollendo to the River Inambari, a tributary of the Madre de Dios, one of the head-waters of the Amazon. That part of the country illustrated in the western half of the section, which includes the important town of Arequipa and the port of Puno on Lake Titicaca, is accessible by the Southern Railway of Peru, of which we were enabled to make full use during the course of our work from Arequipa to the coast, through the kindness of Mr. McCulloch, manager for the Peruvian Corporation. I have also to thank Mr. F. A. Corry, chief engineer of the line, for the original from which the sketch-map (fig. 1) was taken.

For the continuation of the section beyond Puno through the Eastern Cordillera, it was found necessary to proceed northwards as far as Tirapata, a station on the Puno-Cuzco railway, whence access could be gained, by the trail of the Inambari Rubber Company, to the forested region of the Montaña.

The railway between Puno and Tirapata, however, runs more or less parallel to the strike of the chain; and, although the eastern part of the section from Tirapata to the Inambari River has a more northerly trend, and is described under a separate heading, it may be regarded as being practically continuous with that part which lies between Mollendo and Puno.

The journey northwards was done by road, in order that we might examine the intervening country.

After completion of the Arica–La Paz section we travelled northwards from Tacna to Arequipa, a distance of about 150 miles, over the coastal deserts here known as the Pampa de Clemesi and the Pampa de Islay, hoping thereby to obtain an occasional glimpse of the underlying rocks which might prove of assistance to us in an attempt to correlate the two sections. With the same object in view, we made a further journey southwards from Puno round the western shores of Lake Titicaca to the peninsula of Copacabana and the Island of the Sun.

Although the district described in the following pages is one of the best-known areas in Peru, little attention seems to have been paid to its geological features, unless account is taken of the explorations made by those interested solely in its mineral wealth.

In 1886, Dr. F. H. Hatch gave a petrographical description of the volcanic rocks of the Western Cordillera in the neighbourhood of Arequipa; but it is not until comparatively recent years that our knowledge of the district has been increased by the publications of the following authors:—Dr. George I. Adams (1908), Mr. V. F. Marsters (1909), Prof. R. Hauthal (1911), and Prof. Isaiah Bowman (1909), all of whom have confined themselves mainly to an account of the coastal regions.

I must repeat my thanks to Mr. W. E. Balston for enabling me to undertake the work of investigating the country, and to Mr. J. R. Thomas for his assistance and companionship in the field.

II. Main Topographical Features of the Country included in the Second Section (Mollendo to the Inambari River).

From the port of Mollendo, the southern railway of Peru follows the coast towards the south-east as far as the hamlet of Mejia (kilometre 15). Thence turning inland it ascends to the station of Tambo (kil. 30, alt. 1000 feet), situated on a flat plain at a considerable height above the village of that name which lies in a fertile valley on the south.

This coastal region, as it may be termed, is particularly well defined when viewed from a passing steamer. It has been described by Prof. Isaiah Bowman as being composed of gently sloping rock-benches of huge size, formed by the sea, and subsequently uplifted to a height of at least 1500 feet. Along the inner margin of these terraces coves are to be found, like those now seen at many places on the present strand-line, or but little above it.

The same author further cites the discovery, at an elevation of 800 feet, of a clay-bank containing recent shells of the same sort as those now found on the beach, and from this concludes that

> 'after the formation of the terrace at this level and its partial dissection as the result of elevation, it was again submerged long enough and deep enough for the formation of the clay and deposition of the shells; a second uplift then brought the whole above water, and it is this movement that is continuing to-day.'

That a comparatively recent uplift has taken place is manifest from the abundant remains of raised beach preserved along the foot of this shelving plateau, consisting chiefly of angular fragments of gneiss and granite derived *in situ* from the rocks cropping out along the shore. These remains, however, so far as my own observations go, do not extend more than about 50 feet above present high-water mark, and the assumption that the uplift has amounted to as much as 800 feet in recent times and is still continuing at the present day, as held by Prof. Bowman, is, I think, hard to reconcile with facts recorded from other parts of the coast.

I have already shown that the presence of pre-Spanish burial tumuli only a few feet above high-water mark at Arica precludes the possibility of any considerable rise in the last 400 years; a change of level of 4 feet, in fact, might with reason be taken to be the absolute maximum, or such loosely-consolidated mounds must inevitably have been destroyed by wave-action. A rise of 800 feet, if the elevation be considered as having taken place at a uniform rate, would therefore necessitate a period of some 80,000 years.

I have previously suggested that a considerable post-Pleistocene elevation must be assumed, in order to account for the fossil mammalian fauna of the inter-Andean region; and some authors have gone so far as to claim a rise of over 1000 feet in the last 11,000 years, in order to explain the position of the ruined city of Tiahuanacu in its present barren site. Effects due to climatal

changes, however, have probably been underestimated, and I can find no conclusive evidence to show that the elevation has been any more rapid here than on the coast.

The occurrence of marine shells at a considerable height above the sea cannot always be taken as conclusive proof of recent uplift, for they are often carried far inland by sea-fowl, and their remains are sometimes so numerous that they appear to be *in situ*. Another case, one in which human agency is involved, is the accumulation on the high-level pampa of shells thrown from the windows of a passing train ; one species in particular, a delicacy much esteemed by the native population, is consumed daily in large quantities on the journey to Arequipa. The shells become incorporated in the drifting sand, and are often carried some considerable distance from the line, when their discovery is at first very misleading.

From Tambo the line rises in a series of curves somewhat steeply to Cachendo (kil. 55, alt. 3250 feet). Beyond this point the aspect of the country undergoes a remarkable change, for the rocky hills bounding the coastal region become buried beneath a vast desert known as the Pampa de Islay, which, although broken through by isolated rounded hills of granite in the neighbourhood of Huagri (kil. 70), stretches as far as Vitor (kil. 122, alt. 5350 feet). Scattered widely over its surface are magnificent examples of crescentic sand-dunes, the white sand of which contrasts strongly with the general reddish colour of the pampa. These are particularly well developed in the neighbourhood of La Joya, where they are frequently 20 feet or more in height. The prevailing winds, during the first half of the year at least, come from the south-east, and the horns of the crescents point in consequence uniformly towards the north-west, in which direction the dunes are said to advance at the rate of 100 feet in the course of a year.

After leaving Vitor a steep winding ascent is made, through the hills known as the Cerros de la Caldera, to the town of Arequipa (kil. 172, alt. 7550 feet), picturesquely situated in the centre of a well-irrigated and fertile plain.

Throughout this ascent the railway is bounded on its northern side by the deep gorge of the Uchumayo River, which may be regarded as forming the dividing-line between the foot-hills and the main volcanic peaks of the Western Cordillera.

The panorama of these giant snow-capped mountains, apparently towering above the city, although in reality some 10 miles distant, is one of extraordinary beauty. On the north-west lies the jagged ridge of Mount Chachani (19,300 feet), on the south-east the flat-topped Pichu Pichu, while in the centre rises the symmetrical cone of El Misti (18,649 feet).

From Arequipa the railway takes a bold sweep to the north-west, so as to circumvent the foot of Mount Chachani. We chose the more direct route, however, between this mountain and El Misti, following the old Inca trail up the right or northern bank of the River Chili, which here cuts a deep gorge between the two mountains.

Fording the River Sumbay, we rejoined the line at Pucacancha[1] (kil. 130), and, continuing to ascend, reached its summit at Crucero Alto (kil. 187, alt. 14,667 feet).

The descent on the eastern side is at first gradual, then more abrupt to Santa Lucia (kil. 238, alt. 13,250 feet), passing on the way over the narrow neck of land between the twin lakes of Lagunillas and Saracocha.

From Santa Lucia to the copper-mines of Maravillas the river-valley, along which the line is built, is comparatively broad, its floor being covered by a thick deposit of alluvial gravel. Beyond this point, however, it narrows considerably, and is flanked on both sides by hills of steeply-dipping stratified Palæozoic rocks, on the upturned edges of which rests a younger Mesozoic series. This striking unconformity is a conspicuous feature of the landscape, and can be clearly seen from the passing train.

The country north of Puno furnishes little of geological or topographical interest, comprising as it does the broad alluvial swamps left by the receding waters of Lake Titicaca; we, therefore, left the line after reaching Taya Taya in favour of the more direct route south-eastwards by the hacienda of Yanarico and Vilque, where the trail is flanked by isolated flat-topped hills which owe their form to a capping of lava.

The final descent into Puno (alt. 12,540 feet) affords a magnificent view of the lake, backed by the snow-clad peaks of the Bolivian Cordillera in the far distance.

For the continuation of our traverse we proceeded along the line to Cuzco as far as the village of Tirapata, and thence journeyed north-eastwards into the region drained by the head-waters of the Amazon, along the trail of the Inambari gold and rubber companies.

I have previously shown that the Eastern Cordillera of Bolivia constitutes a well-defined range of high peaks, formed of granite and Palæozoic sediments—Mount Illimani, Huaina Potosi, etc. In the district under discussion, however, such is no longer the case; individual peaks, recognizable on a map, are of rare occurrence and scattered over a wide area, and the Cordillera here consists of a number of intersecting ridges which unite farther north in the so-called 'Vilcanota knot.' On the route mentioned above, the divide is crossed at about 15,500 feet, between a little river known as Viscachani and the village of Macusani.

Some 20 miles or more north-east of this point, two much higher snow-capped peaks are visible, the altitudes of which have apparently never been determined. They are known to the natives as Mount Allincapacc and Mount Huainacapacc, and if we judge from the amount of snow on their summits, they must at least rival some of the better-known peaks of Bolivia.

After leaving Macusani, a rapid descent is made down the valley of the San Gaban River, famous as the source of much Spanish gold. This valley shows a very immature stage of development.

[1] Distances are henceforward reckoned from Arequipa.

Its sides are steep, often precipitous, and the river descends in a series of falls and boiling rapids to join the Inambari a few miles below the rubber camp of Chaquimayo.

Numerous small tributary streams enter the main river in the form of hanging valleys, at the mouths of which are fine examples of 'cônes de déjection.' These are remarkably well developed, and control the mighty rush of water in the most striking manner, forcing it repeatedly from one side of the valley to the other.

The trail enters the dense tropical vegetation of the 'Montaña' or forest-region at Ollachea (alt. 8860 feet), and, after several times crossing the river by frail swinging bridges, reaches its termination on the Inambari River at Puerto Seddon (alt. 1575 feet).

III. Geological Description of the Section from Mollendo to the Inambari River. (See Pl. VI.)

For the purposes of geological description, it has been found convenient to divide this section into three parts:—

(1) Mollendo to Arequipa: comprising the ancient metamorphic and intrusive rocks of the coastal Cordillera, the plutonic complex of the Cerros de la Caldera, and the fragmentary remains of a Mesozoic cover.

(2) Arequipa to Puno: comprising the volcanic rocks ejected from the giant cones which fringe the Western Cordillera; the Mesozoic and Palæozoic sediments of the inter-Andean region corresponding to the Altaplanicie of Bolivia; the dioritic intrusions of the Maravillas district; the lava-flows of post-Cretaceous age in the neighbourhood of Puno, and the alluvial flats of Lake Titicaca.

(3) Tirapata to the Inambari River: comprising the Palæozoic sediments and plutonic rocks of the Eastern Cordillera and the Amazon slopes.

(1) The Geological Structure of the Country between Mollendo and Arequipa.

In a former paper dealing with the geology of a section from Arica to the Bolivian Yungas, I described the coast of Northern Chile as being composed of stratified Mesozoic deposits associated with igneous rocks of contemporaneous origin; this series, with its intruded core of granodiorite, was shown to form the basement on which are situated the volcanic cones of the Western Cordillera.

If the coast be followed southwards, however, this Mesozoic zone is soon found to be cut off from the ocean by an intervening zone of ancient crystalline rocks, comprising chiefly granites, gneisses, and mica-schists. Rocks of this nature are well exposed at Mejillones, Coquimbo, Valparaiso, and other intermediate ports; they constitute the coastal Cordillera of Chile.

North of Arica, the Peruvian coast-line bends sharply towards the north-west. This change of direction, though accompanied by a corresponding deflection in the strike, is sufficiently great once more to bring to light rocks that may be regarded as forming the continuation of the coastal Cordillera of the south. Such rocks

fringe the coast from Ilo to Mollendo, and thence are continued northwards.

The fossiliferous coal-bearing beds of Upper Carboniferous age which are found on the peninsula of Paracas, a few miles south of Pisco, must also be included in this coastal zone, as distinguished from the typically Mesozoic zone of the Western Cordillera. This is the only known occurrence of fossiliferous Palæozoic sediments on the whole coast of Peru, and must not be confounded with the statement made by A. d'Orbigny, that the beds of the Morro de Arica are of Carboniferous age, since the latter have now been proved to contain Jurassic ammonites.

The section described in the following pages commences at the port of Mollendo, which is situated on the crystalline rocks of the coastal Cordillera.

The earliest rock of this series is a medium-grained pink gneiss (A 71), composed of irregular alternating bands of quartz, felspar, and dark minerals, of which biotite is alone recognizable in a hand-specimen. The rock is much contorted and fractured, and is traversed by a complicated system of faults. Although there is no direct evidence for its antiquity, it has the typical appearance of an Archæan rock. Forming reefs and low-lying cliffs along the shore as far as Mejia, it is everywhere seen to be pierced by numerous acid veins of pegmatite (A 103) and greisen (A 101), the former consisting chiefly of quartz and microcline, the latter of quartz and muscovite.

Less abundant are basic intrusions in the form of dark microcrystalline dolerite-dykes (A 97), good examples of which crop out on the beach at kilometre 2 and kil. 11. The relationship of the rocks is clearly defined at the first locality, where a 2-foot basic dyke is seen to cut both the gneiss and the minor pegmatite-veins, the latter having been injected parallel to the planes of foliation. The gneiss has further been penetrated by larger masses of plutonic rock, both acid and basic, representing the parent bodies from which the minor intrusions have been derived.

The connexion of the basic dykes with the parent rock is, for the most part, a matter of inference, suggested by their constant association in several localities, and they appear to represent somewhat earlier differentiation-products; in the case of the acid veins, however, the connexion is clearly visible.

The basic rock is a fine-grained holocrystalline diorite (A 70), which forms large reef-like masses on the shore in the immediate neighbourhood of Mollendo, where it crops out from beneath the sands of the coastal pampa. Although of dark colour and basic appearance, with a high percentage of ferromagnesian minerals (chiefly biotite and hornblende), it contains abundant quartz. This, however, in many cases appears to be of secondary origin, occurring in the form of minute veins associated with crystals of pyrites.

(The grey granite used during the construction of the mole, and frequently found washed up in blocks on the beach, does not occur here *in situ*, being quarried farther inland near Tingo.)

The junction of diorite and gneiss is well seen in one of the railway cuttings at kilometre 2, where the former rock along the chilled margin assumes the aspect of a fine-grained amphibolite, while the gneiss has undergone little change. A similar occurrence is to be noted at kil. 13, where the latter rock is again penetrated by a second and smaller mass of diorite with associated basic dykes.

The acid magma has consolidated as a coarse-grained pink granite (A 91), containing clear smoke-coloured quartz, pink felspar, and a small percentage of biotite and chlorite.

The rock is much fractured and weathered. Its junction with the gneiss is plainly seen at Mejia, the latter rock being penetrated in every direction by numerous veins of pegmatite. The presence on the Pacific coast of this typically 'alkaline' type of rock, containing, as it does, abundant microcline and few ferromagnesian minerals, in a district essentially characterized by rocks of a 'calcic' facies, is of considerable interest. It would appear to support the theory of a remote, possibly Archæan, age for the gneiss and granite, by the suggestion that their formation preceded the development of the forces which gave rise to the uplift of the Andes, with the accompanying intrusion of plutonic rocks of 'Pacific' type.

That a generalization of distribution of so-called Atlantic and Pacific provinces cannot be applied to the older rocks, has already been proved by Dr. G. T. Prior[1] in the case of the Great Rift Valley of British East Africa, where a younger foyaitic-theralitic series overlies older crystalline rocks of Pacific kindred. In the present instance the reverse is the case, rocks of an alkaline facies being succeeded by a younger calcic group.

Petrographical Description of the Rocks of the Coastal Cordillera.

(A 71) Gneiss. Mollendo (kil. 2).

Microscopic characters:—This rock consists essentially of a granular mosaic of clear quartz, felspar, and certain coloured minerals, showing marked parallel structure in their arrangement; the effects of dynamic metamorphism have further resulted in the crushing or bending of many of the constituents.

Quartz is abundant, and exhibits pronounced strain-shadows.

The felspars are slightly turbid owing to alteration, which has resulted in a confused mass of sericite-flakes; they comprise microcline, orthoclase, and plagioclase (near andesine), the last-named frequently showing bending and fracture of the twin-lamellæ. The microcline structure, although possibly in some cases original, often appears to be a phenomenon due to strain-pressure acting on the orthoclase.

The micas are not abundant; muscovite and biotite are present in about equal proportions, the latter showing alteration into chlorite and epidote.

A colourless or faintly pink garnet is abundant; the crystals are

[1] 'Contributions to the Petrology of British East Africa' Min. Mag. vol. xiii (1901–1903) pp. 228–63.

intensely crushed and broken, the cracks being filled with a greenish alteration-product which appears to be a variety of serpentine.

Numerous colourless crystals of kyanite are also present, showing the characteristic cleavage and high index of refraction.

Magnetite occurs in somewhat large irregular grains.

(A 91) Granite. Mejia (kil. 15). (Pl. II, fig. 2.)

Microscopic characters:—A coarse-grained holocrystalline rock with typical granitoid structure. It consists chiefly of quartz and felspar, to which the coloured minerals are quite subordinate.

The felspars comprise microcline in large crystals with characteristic cross-hatching, orthoclase, and plagioclase; monoclinic and triclinic forms frequently showing perthitic intergrowths. The plagioclase exhibits very narrow twin-lamellæ, and has a refractive index considerably lower than that of balsam, being nearer albite. Its decomposition has resulted in the production of flaky aggregates of sericite; while, in some instances, the entire centre of a crystal is replaced by a clear patch of brilliantly-polarizing muscovite.

A little biotite is present, but it has been almost completely converted into green chlorite.

The minor accessories include apatite, magnetite, hæmatite, and small crystals of zircon, the last-named occurring as inclusions in the biotite with strongly pleochroic halos.

In addition, there are frequent pseudomorphs of calcite crowded with small yellow crystals, which from their outlines and extremely high refractive index appear to be anatase. These pseudomorphs probably represent original sphene.

(A 103) Pegmatite. Mollendo (kil. 2).

Microscopic characters:—This rock consists essentially of quartz and microcline in coarse pegmatitic intergrowth.

Coloured minerals are almost entirely absent, but muscovite occurs in some abundance, largely in the form of sericite from the decomposition of the felspar.

(A 101) Greisen. Mollendo (kil. 2).

Microscopic characters:—The bulk of this vein consists of an irregular mosaic of clear quartz and brilliantly-polarizing muscovite, although there is also a certain amount of much-decomposed felspar. This appears to have been chiefly orthoclase, but traces of albite-twinning are occasionally visible.

A little biotite, showing conversion into chlorite, is also present.

(A 70) Hornblende-mica-diorite. Mollendo (kil. 1).

Microscopic characters:—A holocrystalline rock of medium grain, consisting chiefly of felspar and ferromagnesian minerals (hornblende and biotite) in roughly equal proportions.

Quartz occurs in some abundance, but appears to be more or less restricted to definite veins, and is therefore probably in great part of secondary origin; analysis of the rock would undoubtedly give a somewhat high percentage of silica.

The felspar is chiefly plagioclase, showing twinning on the albite law; the extinction-angles of sections, cut perpendicular to the lamellæ, do not usually range above 15° (oligoclase-andesine), and the refractive index is about equal to that of quartz.

The ferromagnesian minerals, which are very abundant, and appear to have crystallized simultaneously, consist of green hornblende (with occasional idiomorphic contours) and brown biotite much altered into chlorite and epidote.

Sphene is also plentiful in somewhat large irregular crystals; a few small needles of apatite occur, but iron-ores are very sparingly developed.

(A 99) Near its junction with the gneiss the rock becomes converted into a fine-grained, confused, fibrous aggregate of hornblende, biotite, and chlorite, with abundant grains of magnetite and a little felspar.

Numerous small light-coloured areas of circular outline are also visible in a hand-specimen. These, when viewed microscopically, are found to be composed of a patchwork of clear tremolite-crystals with an occasional large grain of magnetite. Their outline is sharply defined, and they appear to be xenoliths that have undergone metamorphism.

(A 97) Dolerite. Mollendo (kil. 2). (Pl. II, fig. 1.)

Microscopic characters:—This rock, which occurs in the form of dark, compact, fine-grained dykes penetrating the gneiss, is composed of small porphyritic crystals of plagioclase and augite embedded in a micro-crystalline ground-mass.

The plagioclase-phenocrysts are idiomorphic to the augite: they have an elongate lath-shaped habit, and are of a peculiar brownish hue which is due to 'schillerization,' for under a high magnification they are seen to be crowded with ultramicroscopic dust-like inclusions. They exhibit Carlsbad twinning in conjunction with that on the albite and pericline laws, and are comparatively fresh, although after their separation they have undergone a certain amount of corrosion by the residual magma, with the production of a clear selvage of irregular outline and free from schiller inclusions. Extinction-angles indicate a range from oligoclase to andesine.

The augite is a colourless or very pale-green variety, showing numerous interpenetrating twin-growths. It tends to wrap round the felspar-crystals in a subophitic manner, but never completely encloses them. In many instances it has been entirely replaced by scaly aggregates of serpentinous and chloritic material, though some unaltered phenocrysts still remain to indicate the original nature of these peculiar pseudomorphs.

The ground-mass approaches in structure the 'intersertal' of Rosenbusch, consisting of a network of small felspar-laths (chiefly oligoclase) enclosing granules of augite and magnetite, and a small amount of residual glass.

The foot-hills bounding the coastal region between Tambo and Cachendo are composed mainly of holocrystalline plutonic rocks of granitic texture, which are well exposed in the numerous cuttings on the railway. These rocks are usually pink or grey, and consist essentially of quartz, felspar, hornblende, and subsidiary biotite. They have the composition of typical granodiorites; plagioclase is, as a rule, in considerable excess of orthoclase, the percentage of ferromagnesian minerals is not high, and quartz is frequently present in some abundance.

A parallel arrangement of the hornblende-crystals is noticeable in some localities, which suggests slight movement during consolidation. An incipient development of gneissic structure due to earth-stresses, however, must also be regarded as a possible explanation, for similar rocks, probably of the same age, were discovered farther inland, showing every stage of dynamic metamorphism from a coarse-grained plutonic rock to a finely-banded gneiss.

In places, overlying beds of white and reddish quartzite are observed, the age of which, in the complete absence of palæontological evidence, cannot at present be determined. On comparison with similar rocks from the Arica section, however, it is logical to suppose

that they are altered Mesozoic sediments, forming a continuation of the Jurassic zone of the south.

The contact of igneous with sedimentary rock, on which the gold mines of Posco are situated, appears to be an irregular one irrespective of the dip of the strata: a mode of intrusion similar to that described in the case of the batholitic mass of the Llutah and Palca Valleys.

On our journey from the south we met with plutonic rocks of like character in the valley of Moquegua and in the Quebrada de Huaneros, and it is therefore natural to conclude that we are here dealing with the northward prolongation of the same batholite. A definite connexion between the two areas, however, cannot be established, owing to the enormous intervening stretch of desert, the Pampa de Clemesi.

If this granodiorite of Cachendo were the only plutonic rock in the district, the evidence for such a connexion might reasonably be deemed sufficient. But, between the foot-hills of the coast and the high volcanic peaks of the Western Cordillera, occurs a vast plutonic complex comprising rocks of very varied composition; and, as many of these crop out, in isolated positions, from beneath the sand of the desert, it is frequently impossible to determine the relationship that they bear one to the other. In the Cerros de la Caldera, however, where the evidence is more easily interpreted, a clearer sequence can be established, in which at least three distinct phases of plutonic intrusion are represented, separated by definite (though not necessarily long) intervals of time.

The problem, then, consists in proving which of these intrusions corresponds to, or is continuous with, the batholite of Northern Chile.

(A 95) Granodiorite. Posco (kil. 40).

Microscopic characters:—A holocrystalline rock of granitic structure, containing a certain amount of quartz and a little orthoclase.

The bulk of the felspar, however, is a plagioclase showing albite and pericline twinning and occasional zonary banding. The extinction-angles indicate an acid labradorite. Green hornblende is abundant in large idiomorphic crystals which are frequently twinned.

The biotite has been almost completely converted into chlorite, with numerous lenticular masses of yellow epidote lying between the cleavage-planes.

Minor accessories include a little sphene, magnetite, apatite, and a few small crystals of zircon.

(A 72) Granodiorite. Cachendo (kil. 51).

This rock is essentially similar to the last, but of somewhat finer grain, and with a more pronounced pink coloration. The phenocrysts of hornblende tend to have a parallel arrangement.

Microscopic characters:—Compared with A 95, it is seen to contain more abundant quartz and orthoclase, though the latter is still quite subordinate to the plagioclase, which shows marked zonary banding with frequent alteration of the internal zones.

The idiomorphic hornblende is twinned parallel to 100.

The biotite is fairly fresh, and retains much of its original brown colour, though there is a considerable amount of chlorite and epidote.

Magnetite is abundant, but apatite and sphene are not well represented.

In comparing the above-described rocks with the granodiorites of the Arica section, the main points of difference to be noticed are the relatively-greater proportion (in the present case) of plagioclase to orthoclase, the greater abundance of idiomorphic green hornblende, and the frequent occurrence of sphene; moreover, the acid pegmatite-veins with tourmaline, so characteristically developed farther south, here seem to be absent or at least extremely rare.

Beyond Cachendo (kil. 55) we reach the Pampa de Islay, a flat expanse of desert unbroken in monotony, save for the countless sand-dunes and an occasional outcrop of the underlying rock. This stretches as far as Vitor, where it ends against the foot of the rocky Cerros de la Caldera.

In the neighbourhood of Huagri occurs a series of isolated rounded hills of reddish hue, formed of granite, which when unweathered, as in the shallow cutting at kilometre 66, is seen to be a coarsely-crystalline grey rock. It is composed of quartz, felspar (both orthoclase and plagioclase), biotite, and hornblende. This granite is a highly-acid rock, and, as the two felspars are present in roughly equal proportions, it may be described as a typical adamellite. Patches occur, however, composed entirely of quartz and pink orthoclase, with occasional pegmatitic intergrowth, and large plates of biotite often measuring an inch or more in diameter. These patches are occasionally so abundant that the rock presents the appearance of a normal pink granite.

Smaller basic secretions are also met with.

(A 73) Adamellite. Huagri (kil. 65). A specimen characteristic of the main bulk of the rock.

Microscopic characters:—A holocrystalline plutonic rock, with hypidiomorphic granitic structure; consisting essentially of quartz, felspar, hornblende, and biotite.

Clear allotriomorphic quartz is abundant.

The amount of orthoclase present is equal to, or in slight excess of, the plagioclase; it occurs in the form of large plates, without definite crystal boundaries, surrounding and enclosing idiomorphic crystals of the latter (near andesine). This structure is typical of the adamellites, as distinct from the true granodiorites.

Green hornblende and brown biotite are present in about equal proportions, the two minerals being often intergrown. Minor accessories include magnetite, sphene, and a little apatite.

After passing La Joya, one notes occasional exposures of quartzites and sandstones, forming low-lying hills between Ramal and Vitor. These beds doubtless belong to the same series as the quartzites of Posco and Cachendo, but failed to yield any palæontological evidence to prove the connexion.

In the neighbourhood of Vitor, about a mile east of the station, occurs a further isolated outcrop of plutonic rock which has a very distinct individuality; but, as it is completely surrounded by desert sand, it was found impossible to determine its relation with the rest of the series. Its surface is deeply etched by the natural sandblast to which it is exposed, and presents a marked difference in

appearance from the smooth highly-polished surfaces of the fine-grained blocks of basic lava that are found scattered in the vicinity. In a hand-specimen the rock bears a strong resemblance to the well-known syenite of the Plauens'cher Grund, near Dresden, being composed almost entirely of a dull pink felspar and greenish-black hornblende; in microscopic section, however, it appears to be more closely related to the acid end of the monzonite series.

(A 75) Quartz-monzonite. Vitor.

Microscopic characters:—This rock is composed mainly of felspar and uralitic hornblende, with subsidiary quartz, biotite. and minor accessories.

It has a coarse-grained holocrystalline structure, and, with the exception of containing a less amount of biotite, agrees in all essential features with the typical monzonite of the Tyrol.

The plagioclase (oligoclase-andesine) is remarkably free from alteration, although traversed by numerous irregular cracks; it is present in slight excess of the orthoclase, to which it tends to be idiomorphic: the latter is grey and somewhat turbid.

The hornblende occurs in the form of yellowish-green fibrous paramorphs of uralite after augite, which was probably a variety rich in iron, for the uralite is crowded with disseminated grains of magnetite and hæmatite. Indications of dual and multiple orthopinacoidal twinning in the original crystals are still visible.

Quartz is fairly abundant; it appears somewhat dusty, owing to the presence of numerous liquid inclusions which frequently show mobile bubbles.

There is a small amount of reddish-brown biotite showing alteration into chlorite, and the felspar includes numerous minute needles of apatite.

After leaving Vitor (kil. 123) we commence the ascent of the Cerros de la Caldera, and at once meet with a complex suite of igneous rocks, representing, as mentioned above, at least three distinct phases of deep-seated plutonic intrusion. Many of these rocks have been subjected to powerful earth-movements with resultant dynamic metamorphism, and the development of banded or gneissic structure. The gradual passage of a coarsely-crystalline granitoid plutonic rock into a fine-grained gneiss can be clearly followed at more than one locality.

Recrystallization of many of the component minerals is a further well-marked feature; but it is not easy to determine how much of this is due to dynamic agency, and how much to thermal metamorphism of one member of the series by another.

Before I attempt to describe the minute structure of the rocks forming this complex, it will be as well to run briefly over the section, stating the various types met with and the evidence on which a determination of their sequence has been arrived at. The majority of the specimens in my collection were obtained from the actual railway-cuttings, where the exposures were comparatively fresh, and as the line ascends with the most sinuous curves, it is possible that intrusions of the same rock, regarded as separate, might in some cases prove to be in reality connected. This, however, is a point of minor importance in reading the general history of the complex, and the detailed mapping, which alone could have made this clear, would not have repaid the time necessary for the

purpose: for example, the plural description of a single dyke, met with in more than one cutting, would not affect the determination of the relative ages of intrusion and country-rock, provided that the separate exposures were noted as being of the same type.

The earliest rock of the sequence is first seen at kilometre 124, in the form of a granodiorite (A 76) almost identical in character and appearance with that previously described from the foot-hills of Cachendo (A 95), and in all probability belonging to the same phase of intrusion. When this rock is traced up the line, however, it is found to undergo a remarkable change, which on microscopic examination is seen to be due to acidification and entire recrystallization of its constituent minerals.

Quartz, of a faintly pink colour, becomes increasingly abundant, the felspars assume a distinctly green tint, and biotite is extensively developed in little well-defined clusters, replacing to a large extent the hornblende as the dominant ferromagnesian element. The relative proportion of the two minerals, however, is a very inconstant character, varying in the most pronounced manner often in the space of a few inches.

Large basic patches composed almost entirely of hornblende are of frequent occurrence. These appear to represent xenoliths of cognate origin, such as occur elsewhere in the unaltered rock, and their somewhat obscure outline is probably due to a certain amount of admixture during the recrystallization which they have undergone in common with the surrounding mass.

Epidote is everywhere abundant, both disseminated throughout the rock and associated with quartz in the form of epidosite-veins; as a rule these seem to have been formed in pre-existing fissures by a process of leaching from the country-rock, though in some cases they have the appearance of original igneous injections.

No definite line of demarcation between this abnormal rock and the normal granodiorite could be determined, and it is thought to be a hybrid rock or a mixture of two distinct types, in which the effects of dynamic metamorphism are superimposed on those of contact-metamorphism. Its origin is discussed later.

With the further ascent of the line to Quishuarani, the change in the granodiorite is still more remarkable.

The rock assumes a banded character, at first somewhat indistinct with further development of biotite, then becoming increasingly pronounced, until at kilometre 145 it is seen to be completely crushed into a true gneiss of extremely fine grain (A 81), in which the clusters of biotite have been drawn out into thread-like lines, only distinguishable by their dark colour.

The forces which produced so marked a structural change in this rock must have been considerable, and as they seem to have had no effect on the other rocks of the complex, we might safely regard the latter, even in the absence of further evidence, as being of subsequent origin, for there is no reason to suppose that they were of a more resistant nature than the granodiorite. When the

stresses reached a maximum, relief appears to have been afforded by fracture, accompanied by the intrusion of a second type of igneous magma, for at the points where the gneissic structure is most completely developed (kilometres 145 & 149, west of Uchumayo) the rock is seen to be broken through by large basic intrusions in the form of a medium-grained green augite-diorite (A 84).

The constant occurrence of the latter rock in localities where the granodiorite has assumed a gneissic structure, can, I think, only be explained in this way, for the contact of the two rocks is distinct, and there does not appear to be any admixture of the two types, nor can the gneissic structure developed in the granodiorite be explained as having been formed by a process of injection.

The diorite consists chiefly of felspar, augite almost completely converted into a fibrous green actinolite, and a deep-brown biotite. Between kilometres 131 and 132 the granodiorite is again penetrated by a rock of somewhat similar character (A 77), paler in colour and with a considerable amount of unaltered pyroxene present.

The diorite forms the sides of the railway-cuttings and the river gorge between Uchumayo and Huaico (kils. 149–160). Like the granodiorite, it is frequently traversed by small veins of quartz and epidote, and near kilometre 153 it is associated with rocks resembling phyllites, which have the appearance of highly-metamorphosed sediments.

Near the station of Tiabaya, between kilometres 160 and 164 and again at kilometre 167, it is itself penetrated by a medium-grained grey granite or adamellite (A 85), representing the third and last phase of plutonic intrusion. This rock is composed of clear quartz, white felspar, hornblende, biotite, and small yellowish-brown crystals of sphene. Epidote, so abundant in the other members of the series, is typically absent. In general appearance it is not unlike the granite described above as cropping out in the desert near Huagri; but, owing to the isolated position of the latter, the correlation of the two is only a matter of conjecture.

Near the zone of contact the granite contains numerous basic inclusions of diorite, and it is obvious that these are fragments plucked off and partly absorbed, in the nature of accidental xenoliths ('enclaves énallogènes' of Prof. A. Lacroix).

The diorite shows clear signs of contact-metamorphism, chief of which is the formation of green hornblende in crystals of large size; it has also been considerably acidified by admixture with the granitic magma.

Locally, near the margin of contact, it assumes a finely-banded appearance, with the development of abundant minute flakes of biotite. This character, owing to its limited extent, is more probably the result of fluxion of the diorite, rendered viscous by the intrusive granite, than the effect of dynamic pressure; the microscopic features of the rock, in fact, are such that it appears to have been completely melted and recrystallized.

In discussing the general history of the complex, the three phases of intrusion, which may conveniently be termed the granodioritic, the dioritic, and the granitic, must be studied independently, although it will be seen that they are, in all probability, intimately connected; the magmas from which they were derived, moreover, may at one time have been coexistent in the same deep-seated reservoir.

In order that many of the observed phenomena may be more readily explained, it is necessary to assume that a certain degree of magmatic differentiation had been arrived at prior to the first intrusion. The granodiorite may then be regarded as representing more or less the normal composition of the original magma, from which the granite and diorite were derived as differentiation-products; the former richer in silica and alkalis, and the latter richer in ferromagnesian elements and lime.

In describing the granodiorite as the first phase of intrusion, it is important to note that this rock contains numerous basic patches, which in some places become so abundant that they completely alter its appearance. These are regarded as portions of dioritic magma, already in part consolidated, which have been incorporated in the residual magma and have undergone complete recrystallization, either in the process of digestion, or by the subsequent metamorphism to which the entire series has been subjected. The deep-seated origin of these xenoliths is assumed from the fact that no outcrop of basic rock earlier than the granodiorite was anywhere discovered.

The normal granodiorite, with its xenoliths of diorite, appears, next, to have been invaded locally by a highly-acid magma representing the other extreme end of the differentiation series. The result has been an admixture of the two types with the production of a hybrid rock of peculiar character. For the sake of distinction, I have termed this the abnormal granodiorite.

Beyond the limit to which actual assimilation of the earlier rock took place, there appears to be a considerable zone of contact-metamorphism, but the effects due to the one cause or the other are not readily distinguishable; they are, naturally, intimately connected, and therefore differ only in degree. Where the basic xenoliths of the original rock, however, are seen to retain their individuality, it may be assumed that the limit has been passed.

(At one time I thought that the acidification of the granodiorite might be due to assimilation of an original quartzite cover, but the appearance of the quartz-mosaic under the microscope makes it quite improbable that such was the case.)

Before discussing the origin of the xenoliths, some mention must be made of the metamorphism which they have undergone since their incorporation in the granodiorite. Three factors have to be taken into consideration. First, the effects produced by their initial capture and partial digestion; secondly, the effects due to the approach of the acid magma; and last, the effects of dynamic metamorphism. It is by no means easy to discriminate between them.

The most important change that can, I think, be referred to the first of these stages, is the complete recrystallization of many of the component minerals. This has resulted in the development of a deep-green strongly-pleochroic hornblende, in idiomorphic crystals remarkably fresh in character, and quite distinct from the pale yellowish-green variety found in the normal granodiorite.

The felspar, too, has been entirely recrystallized, and occurs in large clear crystals, in which are scattered abundant inclusions of magnetite in quadrate grains, and minute granules and prisms of hornblende. This new felspar appears to have the optical characters of andesine, and we may therefore infer that there has not been much change from the acid labradorite of the original rock.

In this connexion it should be noted that there is not very much epidote present here, whereas in the bulk of the granodiorite which has been acidified by admixture this mineral is abundant. Biotite in fresh unaltered crystals occurs in association with the hornblende; the latter, however, is usually idiomorphic to it. It is doubtful whether its origin should be attributed to the first stage of metamorphism, although it has the appearance of having been entirely recrystallized in common with the felspar and hornblende: for, in the hybrid rock produced by admixture of the normal granodiorite with the residual acid magma, it is seen to become, more and more, the dominant ferromagnesian mineral at the expense of the hornblende, from which, indeed, it appears in great part to have been formed. Moreover, where the latter rock has been crushed, hornblende entirely disappears, whereas biotite is persistent, a fact which suggests that its development may have taken place *pari passu* with the structural change.

Saussuritization of the outer zones of some of the felspars, together with fracture and dislocation of many of the hornblende-crystals, is a proof that they were formed prior to the development of the earth-stresses, and affords an indication that these were already beginning to make themselves felt.

From this stage, where no marked structural changes are visible in a hand-specimen, a complete transition can be traced into a fine-grained, intensely-crushed and banded gneiss, in which the effects of dynamic metamorphism have almost completely obliterated the original characters of the rock.

Before describing this change, however, attention must be directed to the contact-metamorphism of the normal granodiorite by the invading residual magma of highly-acid character. As has been mentioned above, it is not easy to distinguish the effects of contact from those of admixture.

The hybrid rock is characterized by an abundance of free silica, in the form of a coarse quartz-mosaic, of dusty appearance (owing to numerous inclusions), and by the presence of biotite in the form of aggregates of fresh unaltered crystals.

The felspars vary according to the proportion of the invading magma present in the rock. In acid types they are chiefly alkaline,

and show sericitization; but, where the granodiorite is in excess, andesine is the dominant form. A few crystals show the original inclusions of magnetite and hornblende; but more usually they are seen to be in the process of recrystallization, with the production of a mosaic of secondary felspar of similar or slightly more basic composition.

Occasional deep-green crystals of hornblende are taken to represent xenocrysts derived from the basic patches, suggesting that the recrystallization of these had already taken place prior to the invasion of the acid magma.

The origin of the biotite clusters is of especial interest. Two possible sources suggest themselves:—

(1) That they are primary derivatives from the acid magma, of the nature of small glomeroporphyritic aggregates, formed in the normal order of crystallization. (2) That they are secondary products of metamorphism, built up at the expense of other minerals.

An examination of the altered granodiorite in the immediate neighbourhood of the acid rock supports the latter view. The characteristic green hornblende is here seen in process of conversion into a yellowish-green chloritoid substance, with which are associated abundant grains of magnetite and crystals of epidote. A segregation of these coloured minerals into patches is already noticeable, which it is not easy to reconcile with a simple process of contact-metamorphism alone, unless the rock has been rendered sufficiently viscous for diffusion to have taken place. By reabsorption of the magnetite the green chlorite becomes deep brown, and is gradually transformed into biotite.

Where the biotite clusters are fully developed the chlorite is typically absent, the magnetite has decreased considerably in quantity, and the green hornblende has almost entirely disappeared.

The granodioritic phase was brought to a close by the development of powerful orogenic movements, which produced intense crushing in these earlier-formed rocks of the complex. The dynamic action, however, was chiefly marginal in effect, and hence the most pronounced metamorphic phenomena attributable to this cause are not of wide extent.

The resultant changes which the rocks have undergone are both structural and mineralogical in character. Although the former are, of course, the more obvious, the latter make their appearance first, and indeed are observed before any actual deformation of the rock is noticeable. It is only by tracing such changes laterally from the seemingly unaltered rock into the crushed and banded gneiss that the true nature of their origin becomes apparent.

The characteristic green hornblende, for example, is then seen to have been formed prior to the crushing, for obvious effects of mechanical action are displayed in the breaking-up of well-defined crystals along cleavage-cracks and subsequent shearing into innumerable small rhombs and prisms, groups of which, more often than not, retain their optical continuity.

Moreover, except in the case of the gneiss formed by the crushing of the granodiorite where it was rich in basic xenoliths, in which hornblende was originally present in great abundance, this mineral is not characteristic of the banded rocks, and in specimens showing the most advanced stage of deformation it has almost completely disappeared.

In any process of orogenic movement the rocks involved must necessarily be subjected to tension as well as to compression, but in many descriptions of dynamic metamorphism it is not unusual to find that too much importance is attached to the latter factor.

It is conceivable, however, that the banding of a gneiss might in some cases be due to stretching alone, and indeed a study of the various stages of the dynamic action exhibited in the present suite of rocks suggests that tension has played a very prominent part in the production of the gneissic structure. For example, the drawing-out of more or less circular patches of biotite-flakes, first into lenticles and finally into long thread-like lines, is more readily explained by such a process than by one of squeezing or rolling-out due to compression: for, in a flexible mineral of this nature, the effects of the latter would be rendered obvious (as is not the case here) by bending and distortion of the lamellæ.

That the biotite may have been in part formed *pari passu* with the movement has already been suggested, but that its origin dates from a comparatively early stage in the metamorphism is clear from the evidence cited above.

The effects of dynamic action are indicated in the quartz at an earlier stage than in the felspar. First, optical disturbances make their appearance in the form of strain-shadows; a coarse mosaic is then developed by granulation; and finally by increased pressure, together with solution and concomitant crystallization, this becomes broken up and converted into a mosaic of extremely fine texture, composed of minute interlocking grains. Comparatively large patches of clear recrystallized quartz are often seen to have been formed under the lee of a felspar-crystal which has protected them from further granulation.

Mechanical action is clearly shown in the case of the felspars by the bending and fracture of the twin-lamellæ, by the production of secondary lamellæ in the plagioclase, and microcline structure in the orthoclase. The final product is a felspar-mosaic produced by granulation.

That the force has been in many cases one of tension is indicated by the separation of fragments produced by fracture, the intervening spaces becoming filled with secondary quartz and felspar. In the case of compression, overthrusting of the fracture is frequently noticeable.

Apart from purely mechanical effects, the dynamic stresses have lent increased power to the agency of solution, and in this way have probably been largely instrumental in causing the recrystallization of the plagioclase in the form of albite, by the removal of lime as calcite or epidote: for, where the change appeared to be due

to contact-metamorphism alone, the secondary felspar was found to differ but slightly from the original andesine, being in fact slightly more basic. The change is accompanied by removal of the inclusions, and by a gradual obliteration of the twin-lamellation.

One of the last stages of metamorphism before the final granulation takes place, is marked by a pronounced sericitization of the alkaline felspars, and thus it seems that this must also be attributed to dynamic agency.

The following descriptions give a more detailed account of some of the leading types :—

(A 76 *a*) Xenolith in granodiorite. (Kilometre 129.) (Pl. II, fig. 4.) A specimen selected from one of the basic patches which appear to be included xenoliths of an earlier-formed rock. A coarse-grained, holocrystalline, melanocratic rock composed largely of ferromagnesian minerals (hornblende and biotite).

Microscopic characters :—The rock has the appearance of having been entirely recrystallized: the three chief constituents—plagioclase, hornblende, and biotite—being remarkably fresh and free from alteration-products. No effects that can be attributed to dynamic metamorphism are noticeable, and it is probable that the recrystallization was the direct result of incorporation by the granodiorite magma.

The felspar, near andesine, occurs in the form of relatively-large clear crystals, characterized by abundant inclusions of quadrate grains of magnetite and minute prisms and rounded grains of hornblende. Twin-lamellation is often ill-defined.

A strongly-pleochroic deep-green hornblende is abundant; it tends to show idiomorphic contours to the biotite, which is also present in considerable quantity. Both minerals seem to have recrystallized in common with the felspar.

Stout prisms and needles of apatite are fairly numerous, and epidote, sphene, and calcite occur sparingly.

Magnetite is chiefly confined to inclusions in the felspar.

(A 76) Metamorphosed granodiorite. (Kilometre 129.) A specimen showing the result of invasion and metamorphism by an acid magma.

In a hand-specimen this rock is almost identical with the granodiorite of Posco (A 95).

Microscopic characters :—The rock consists essentially of quartz, felspar, and hornblende, with secondary biotite and epidote, and accessory sphene, apatite, and magnetite.

The ragged outlines of the felspar and hornblende show clearly the effects of corrosion by the invading magma, which has consolidated in the form of a coarse quartz-mosaic.

Hornblende is abundant, and has the appearance of having been recrystallized. It is intensely pleochroic, with colours ranging from yellow to a deep bottle-green. The crystals are often fractured, the spaces between the separate fragments being filled with secondary quartz and felspar.

Biotite is not abundant; it is here seen in process of formation from large patches of green chlorite crowded with magnetite and epidote, which are being produced at the expense of the hornblende.

Clear andesine-crystals with inclusions of magnetite and hornblende, as in A 76 *a*, are occasionally noticeable; but for the greater part the felspar appears to be in process of recrystallization. The secondary felspar forms a fine granular mosaic similar in appearance to micropegmatite—in fact, except for an occasional indication of twinning, it is not easy to

distinguish it from the quartz with which it is associated. Its refractive index is higher than that of the original andesine, and it would therefore appear to be a more basic variety, the addition of lime being possibly explained by the disappearance of the numerous inclusions of hornblende. The change is accompanied by a gradual loss of twin-lamellation.

(A 83) Metamorphosed granodiorite. (Kil. 149.) A specimen intermediate in character between the abnormal acid granodiorite and the true banded gneiss into which it passes. The effects of dynamic action have now become well marked.

The rock has a peculiar and characteristic appearance in a hand-specimen, due to the development of clusters of biotite. Much of the felspar is of a dull greenish colour, suggestive of saussuritization.

Microscopic characters:—Hornblende has now entirely disappeared, and the chloritoid patches have been converted into aggregates of clear biotite-flakes, most of the magnetite having been absorbed in the process. Occasional clusters of magnetite-grains associated with epidote, however, are also visible.

Although a certain amount of andesine is still present, the bulk of the triclinic felspar appears to be albite, having a refractive index distinctly lower than that of quartz and balsam. That this change may be regarded as one of saussuritization is shown by the numerous aggregates of zoisite-grains scattered throughout the felspar substance. With these are associated larger grains of epidote and a green mineral, showing pleochroism and a moderately-high double refraction, which appears to be hornblende. In addition to these inclusions, the alkaline felspars are crowded with flakes of colourless mica, a type of alteration which seems to belong to a comparatively late stage in the dynamic metamorphism.

Peripheral granulation of the felspar-crystals, which ultimately leads to the formation of an albite-mosaic, is also visible, and the orthoclase shows indications of microcline structure.

(A 81) Gneiss. (Kil. 145.) This specimen represents the most advanced stage in the dynamic metamorphism of the granodiorite, being the final product in the transition from A 83.

It is a uniform pink banded rock of splintery fracture and extremely fine grain. The ferromagnesian minerals are no longer recognizable, each individual crystal or group of crystals having been drawn out into microscopic thread-like lines.

Microscopic characters:—The rock exhibits pronounced cataclastic structure. The coarse quartz-mosaic has become crushed or drawn out in the direction of movement, individual grains having been fractured, ground down, and rewelded into a finer mosaic, together with a mass of clear recrystallized felspar.

A few of the larger crystals of felspar having partly escaped this grinding process, except for marginal granulation, remain embedded in the granular matrix (mortar-structure), and show distortion and fracture of the twin-lamellæ.

Hornblende is entirely absent, and the scaly aggregates of biotite have become elongated into flattened lenticles or long drawn-out lines.

A few crystals of apatite still persist; but epidote and magnetite are not abundant.

(A 79) Basic gneiss. (Kil. 139.) (Pl. II, fig. 3.) This specimen shows the effect of intense dynamic action on the more basic type of granodiorite rich in xenoliths.

Microscopic characters:—The constituent minerals have a strongly-marked parallel arrangement. Biotite and hornblende are present in about equal quantity, and tend to occur in alternating bands—due to the breaking-up and drawing-out of individual crystals.

The original crystals of hornblende have broken along their cleavage,

and have been sheared into innumerable small prisms and rhombs, groups of which still show optical continuity.

Distortion and fracture of the plagioclase is very well marked. A feature of the rock is the extensive development of magnetite, in the form of minute grains scattered throughout the hornblende and biotite.

The second or dioritic phase was marked by the intrusion of melanocratic rocks of basic character.

Although for the greater part these have undergone profound modification, their original composition can be determined from some of the less altered examples which may be classed with the augite-diorites. In many cases, however, the pyroxene has been almost completely converted into fibrous hornblende. The almost constant association of these unbanded rocks with the gneissic modification of the granodiorite has already been noted. They are unaffected by the forces which produced such intense deformation in the latter rock, and are therefore regarded as constituting a distinct phase of intrusion, their localization having been determined by lines of weakness which were evidently developed in areas of maximum deformation. Although the dynamic stresses never again attained such a degree of magnitude, the abundant quartz-epidote veins which mark lines of fracture in both the diorite and the older rocks show that the district was still subjected to considerable earth-movements. The mineralogical changes which have affected the diorite over wide areas, as exemplified by the uralitization of the pyroxenes and the saussuritization of the felspars, cannot be ascribed to any mere process of weathering, or even to contact-metamorphism: for the distinctive effects of the latter, to be described later, are clearly exhibited where the rock is penetrated by the acid magma of the third or granitic phase.

It would appear, therefore, that their origin must be attributed to some other cause, and the most plausible suggestion is that they are the effects of waning dynamic action which was no longer sufficiently great to produce macroscopic structural change. This theory is supported by microscopic investigation.

The most distinctive feature of the altered rock is the fact that, when viewed with ordinary light, each individual crystal, almost without exception, is clearly defined by an opaque dust-like margin. Under a high magnification this is seen to be composed of minute granules, which appear to be chiefly epidote. The rock, then, has been rendered completely permeable to solution from the large epidote-lined fissures with which it abounds, down to the finest capillary cracks: the bulk of the epidote being evidently derived from the pyroxene during its conversion into hornblende.

This pronounced permeability, which is not possessed to the same extent by the coarser granodiorite (although the latter contains much disseminated epidote), appears to be due to incipient granulation of an even-textured rock of relatively fine grain, as a result of the action of dynamic stresses.

Further evidence of internal movement is also afforded by the biotite, which occurs in the form of somewhat large plates that

have been fractured and sheared into irregular fragments, still preserving their optical continuity, though separated by patches of clear plagioclase and quartz. This feature, in fact, is even visible in a hand-specimen, the plates of biotite giving a distinctive lustre-mottling to the rock.

(A 77) Augite-diorite. (Kil. 132.) This rock consists essentially of plagioclase, a colourless augite and biotite, with a little quartz and orthoclase and accessory magnetite, apatite, epidote, and chlorite.

The plagioclase (medium labradorite) is clear and fresh, showing twinning on the albite and pericline laws. It is in considerable excess of the orthoclase, to which it is idiomorphic.

Chestnut-brown biotite and a pale-green or colourless augite are present in roughly equal proportions, the former showing alteration into chlorite and epidote. The augite occurs in the form of irregularly-bounded crystals, showing multiple twinning and incipient alteration into a fibrous uralitic hornblende.

A small amount of interstitial quartz, magnetite in some abundance, and a little apatite are also present.

(A 84) Saussuritized diorite. Huaico (kilometre 156). This rock is a modification of the foregoing, in which the pyroxene has been almost completely converted into a bluish-green fibrous actinolite, frequently showing a fringe of secondary biotite.

A deep-brown biotite also occurs, in the form of large irregular plates usually surrounding magnetite.

Although a considerable amount of plagioclase is clear and unaltered, most of the larger crystals are opaque with decomposition-products: these consist chiefly of minute highly-refracting prisms and granules, which between crossed nicols show the bright interference-colours of epidote and the deep blue of zoisite, the change therefore appearing to be one of saussuritization. It is difficult to determine the nature of the original felspar, but the extinction-angles when visible suggest that it was less basic than the unaltered crystals, which are acid labradorite.

The general appearance of the section, however, makes it not improbable that we are dealing here with a mixed rock, and the fresh felspar and most of the quartz, which occurs in some abundance, may have been derived from an extraneous source.

The third and final phase in the sequence was marked by the intrusion of a granitic magma of acid character, probably derived from the same deep-seated reservoir as that which furnished the acid magma which invaded the granodiorite. Its intrusion, however, is obviously of much later date, for it has nowhere been affected by the dynamic stresses which produced so marked a structural change in the latter rock. It is seen, moreover, to be posterior to the dioritic rocks of the second phase, for these show clearly the effects of contact-metamorphism at the points of junction.

The typical rock of this granitic phase is a coarse-grained grey adamellite, very similar in appearance to the rock previously mentioned as cropping out in the desert near Huagri. It is extensively quarried, for building-purposes, in the neighbourhood of Tingo, and has been used in the construction of the mole at Mollendo. Near its junction with the diorite it contains numerous

small basic patches, which are obviously fragments of the latter rock plucked off and partly absorbed. These xenoliths have been almost entirely recrystallized, with the development of relatively-large phenocrysts of a strongly-pleochroic deep-green hornblende; traces of original augite with multiple twinning, however, are still visible.

The diorite along the margin of contact appears to have been completely fused, and has assumed a finely-banded structure due to fluxion.

The subsequent recrystallization of the component minerals throws considerable light on the origin of the xenoliths in the granodiorite of the first phase, the marked similarity of the resultant products of metamorphism in the two cases being a strong argument in favour of the theory that the latter were derived from a deep-seated dioritic magma, although this does not appear to have been drawn upon extensively until a later period in the history of the complex, as exemplified by the rocks of the second phase

In the case of the earlier xenoliths, owing no doubt to a higher degree of viscosity, there seems to have been but little fluxional movement, and as a result, the growth of individual crystals was unrestricted. In the present case, however, the diorite was rendered completely molten by the invading granite, and movement taking place during consolidation, the crystals were broken up as they formed, and in consequence never attained large dimensions.

There is direct and unmistakable evidence that the secondary green hornblende has here been derived from pyroxene, even though the latter had in some cases been uralitized previous to recrystallization. It is not unreasonable, then, to conclude that the xenoliths in the granodiorite also had their origin in a pyroxene-bearing diorite: for, notwithstanding the difference in texture of the two rocks, their mineralogical characters are almost identical; the resemblance being especially well shown in the case of the glassy-clear recrystallized andesine, with its abundant minute inclusions of hornblende, biotite, and magnetite (see Pl. II, fig. 4).

(A 85) Adamellite. Tiabaya (kilometre 161). This rock consists essentially of quartz, orthoclase, plagioclase, hornblende, and biotite, with accessory sphene, magnetite, apatite, and zircon.

Clear quartz is abundant.

Orthoclase occurs in large plates surrounding idiomorphic crystals of plagioclase (andesine–acid labradorite), showing albite-twinning and zonary structure. The two forms are present in about equal proportions, and are remarkably clear and fresh.

The ferromagnesian minerals, which are quite subordinate to the felspars, comprise idiomorphic green hornblende, twinned parallel to 100, and brown biotite showing alteration into chlorite.

Magnetite and sphene are of fairly-common occurrence, the latter in well-developed crystals.

Apatite and zircon occur sparingly.

Associated with the adamellite, and veining both this rock and the older diorites, are a few fine-grained acid dykes. These consist of quartz and turbid orthoclase, often in micropegmatitic inter-

growth, subsidiary plagioclase, a little biotite mostly altered to green chlorite and epidote, some magnetite and apatite, and a small amount of tourmaline with characteristic blue and brown pleochroism.

The last-named mineral, however, is never abundant in this area, in which respect the rocks of the complex differ in a marked degree from those of the plutonic batholite of the Arica–La Paz section, where tourmaline-pegmatites are of common occurrence; moreover, it is found here in the form of small isolated crystals, and not in the coarse radial aggregates so typical of that district.

The several stages in the general history of the complex may be summarized as follows:—

(1) The intrusion, probably into Mesozoic strata, of the Quishuarani granodiorite, comparable with that of the Cachendo foot-hills.
(2) Its invasion by a residual acid magma.
(3) Its subjection to powerful earth-stresses, which produced intense dynamic metamorphism, with the local development of gneissic structure, and culminated in:—
(4) Fracture, with the intrusion of the augite-diorite of Huaico.
(5) Formation of numerous quartz-epidote veins.
(6) Intrusion of the Tiabaya granite (adamellite) comparable with that of Huagri, producing contact-metamorphism of the diorite.
(7) Final intrusion of minor acid veins containing tourmaline.

(2) The Geological Structure of the Country between Arequipa and Puno.

The Uchumayo Valley, as has already been mentioned, forms a natural line of division between the Cerros de la Caldera and the lofty peaks of the Western Cordillera. On its south-west side lies the plutonic complex just described, while on the north-east is found a thick accumulation of bedded volcanic tuffs, ejected from Mount Chachani and El Misti.

Prior to the cutting of the valley, these tuffs must have extended far towards the coast, for their scattered remains are frequently visible lying as a denuded mantle on the older rocks. Isolated blocks of lava are even met with as far as Vitor; but, as a rule, the eruptions seem to have been chiefly of an explosive nature, resulting in the formation of well-bedded compact tuffs, pure white or of a pink colour, containing abundant fragments of pumice. These tuffs are extensively quarried in the neighbourhood of Arequipa for building-purposes.

True lavas are more or less confined to the vicinity of the mountains. They have already been fully described by Dr. F. H. Hatch, and it is therefore hardly necessary to make more than a passing reference to them here. That author has shown that most of the lavas of the Arequipa district belong to the andesite group, and he has further subdivided them, according to their dominant ferromagnesian mineral, into hornblende-andesites, augite-andesites, hornblende-augite-andesites, and andesites with hypersthene in addition to the former minerals.

Many of the hornblende-andesites bear a striking resemblance to the trachy-andesites described by me from Mount Taapaca in Northern Chile, while the augite-andesites are very similar to those from Mount Tacora.

The volcanic peaks, with the exception of Ubinas a little farther south, which was smoking at the time of our visit, are no longer active, though El Misti still preserves a remarkably fine crater, and signs of latent activity are not wanting in the district.

The effects of a small volcanic earthquake which occurred on April 28th, 1911, were described to me by Mr. Vogel, of Arequipa. While looking down from the astronomical observatory he noticed a thick cloud of dust passing like a sudden wave through the city, and at the same time felt a distinct earthquake shock. He afterwards found that the dust was due to the collapse of buildings constructed of 'adobe' and light volcanic tuff. The wave had left a well-defined track in its wake, on either side of which the houses remained unaffected. Such an extremely-localized shock suggests the formation of a subterranean fissure or dyke.

Some distance north-east of El Misti, in a little tributary valley of the River Sumbay, we also encountered numerous hot springs highly charged with sulphuretted hydrogen and alkaline salts.

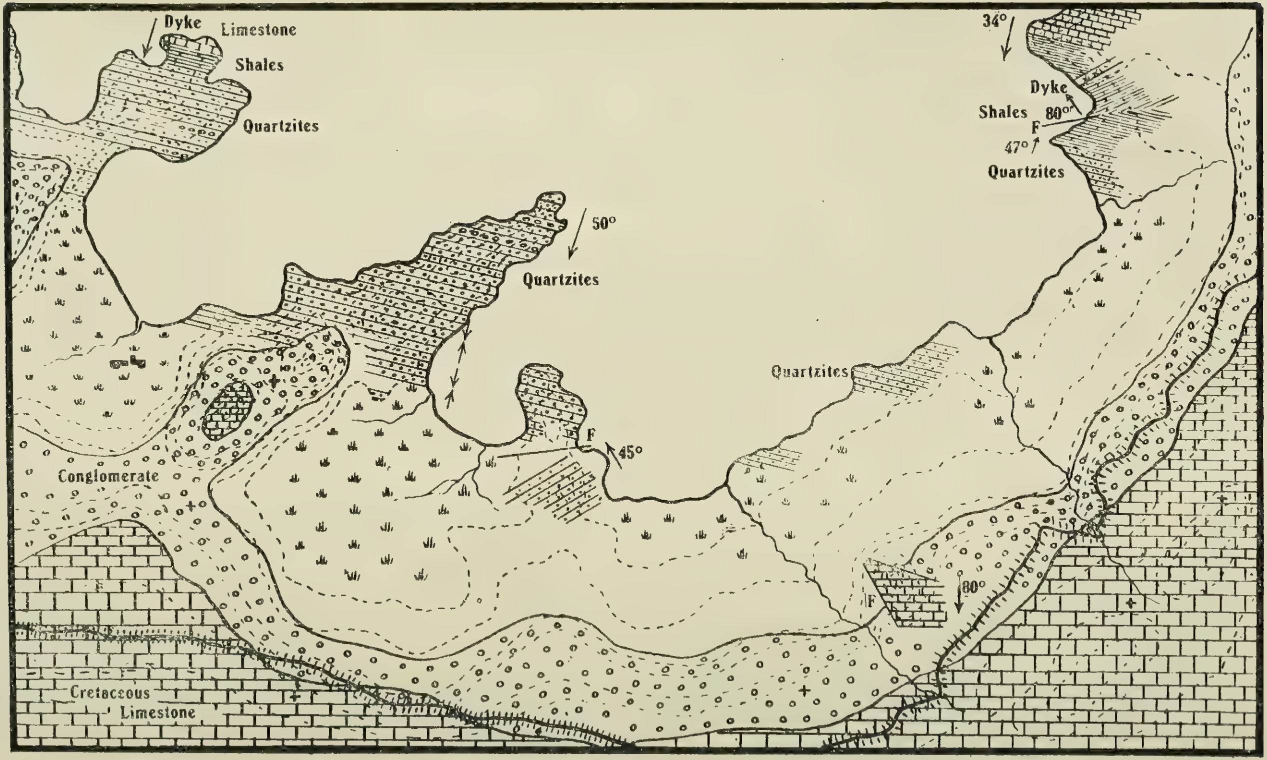
The general sequence of the volcanic deposits is well exposed in the valley of the River Chili, the railway-cuttings round the foot of Mount Chachani, and in the gorge of Uyupampa beyond Yura. Here, too, they consist chiefly of false-bedded, white, yellow, and grey tuffs, with occasional darker bands of coarse ash.

When the line is followed towards the east, the country is found to be very like that of the Mauri-River district in Bolivia, for it is buried beneath a thick mantle of pumiceous tuffs which give the same peculiarly monotonous aspect to the landscape. In many localities, however, the surface is relieved by fine examples of 'Zeugen' or rock-tables, formed of hard blocks of lava capping pillars of less resistant tuff which have been undercut by the erosive action of wind and rain. In places these are so numerous that they are termed by the natives 'rock-forests.' The tuffs frequently exhibit polygonal jointing on a very minute scale.

In addition to this volcanic covering, the structure of the underlying country is further obscured by extensive swamps and thick alluvial gravels, composed chiefly of pebbles of quartzite and rocks of igneous origin; these sometimes cover wide tracts, such as that between Vincocaya and Crucero Alto, and have the appearance of being old lake-deposits. The quartzite-pebbles have evidently been derived from a series of beds which only occasionally crop out at the surface.

Rocks of this nature were first met with on the banks of a small tributary of the River Sumbay, where they were found to consist of unfossiliferous white quartzites, dipping 10° south-westwards. They are broken through by a small volcanic neck filled with a coarse agglomerate. Similar beds of quartzite also crop out on the road to Pucacancha, and occasionally form low hills bounding the alluvial flats between this point and the summit of the line.

Fig. 2.—*Sketch-map showing the Cretaceous unconformity at Lagunillas. Approximate scale, 1 : 15,000.*



In the complete absence of palæontological evidence, they are here provisionally regarded as forming the continuation of the Mesozoic (probably Jurassic) zone of the foot-hills.[1]

After crossing the divide at Crucero Alto, and continuing in the direction of Lagunillas, we meet with a further series of igneous rocks (at kilometre 204), which appear to be totally distinct from those described above as lying within the volcanic zone of the Western Cordillera. They consist, for the greater part, of dark amygdaloidal basalts, weathering brown or red, and containing abundant traces of copper in the form of carbonates.

The amygdules are usually filled with calcite or chalcedony, and small porphyritic crystals of augite are also visible in the groundmass. These lavas are associated with beds of coarse volcanic breccia, which contain blocks of lava, sometimes more than a foot in diameter, set in a matrix of white tuff. Such beds appear to have been formed by a brecciation of the lava *in situ*.

Beyond Lagunillas Station a further change takes place in the nature of the landscape: the volcanic covering has entirely disappeared, and the structure of the underlying country again becomes visible. The railway-cuttings between this point and Saracocha reveal a thick series of grey cherty limestones. These beds cap the hills on the south of the lake, and have, in some cases, the appearance of reef-knolls, occurring in more or less isolated masses which pass laterally into red marls. They are frequently much dolomitized, and included fossils are extremely rare; a few weathered fragments of echinoderms and lamellibranchs were obtained, however, and these leave little doubt that the limestones are of Cretaceous age, having been formed during the period of wide transgression which is represented in the north by a limestone series of similar appearance, but of extremely fossiliferous character.

At the base of the Saracocha limestone occurs a thick purple conglomerate, which rests with marked unconformity on an underlying series of quartzites and shales, with occasional dark-grey limestones (see sketch-map, fig. 2). This conglomerate is well stratified, and frequently contains bands of red marl, devoid of pebbles. Its lowest beds are composed almost entirely of quartzite-pebbles derived from the underlying rocks, while those above contain abundant well-rounded pebbles of igneous origin (chiefly porphyrites and hornblende-diorites), together with scattered subangular and rounded blocks and pebbles of cherty limestone, evidently derived *in situ*.

The source of the igneous pebbles is a matter for some speculation. They are composed, for the most part, of rocks entirely dissimilar to any found in the district, and it is only possible to conclude that they were derived from an older series of plutonic rocks with their

[1] Dr. Erich Jaworski mentions the occurrence of Bajocian-Bathonian beds at Lumbay (Sumbay ?) on the railway from Arequipa to Puno, from the discovery of cherty limestone with *Nerinea bathonica* Rig. & Sauv., Neues Jahrb. Beilageband xxxvii (1913) p. 305.

Fig. 3.—*Horizontal Cretaceous beds lying unconformably on folded Jurassic, Lagunillas.*

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associated dykes, which formerly cropped out farther west, but are now completely concealed by the Tertiary volcanic covering.

The diorite of Maravillas, described below, to which they bear some resemblance, breaks through the limestones, and is obviously an intrusion of post-Cretaceous age.

The red marls with which the limestones are associated are very similar in appearance to the Cretaceous marls of the Coro Coro district of Bolivia, and the thinning-out of the limestones when followed in this direction shows that, while the country in the north gradually became depressed beneath the waters of the Cretaceous sea, shallow-water conditions continued to prevail in the south.

The conglomerates and overlying limestones undulate but slightly in the neighbourhood of Lagunillas. Between the two lakes, however, they show indications of being much faulted, and dip steeply until they reach the valley-floor, the conglomerate attaining its greatest development in the rugged cliffs bounding the eastern basin.

The physiography of the district is also of considerable interest, and it is a matter of some difficulty to account for the origin of these twin lakes, separated by a steep though narrow neck of land. The most probable solution is that they owe their position to faulting on a large scale.

Numerous instances of minor faults, affecting both the Cretaceous and the underlying rocks, are, indeed, visible along the shores of Lagunillas, where they are occasionally associated with igneous intrusions in the form of small basaltic dykes. Although these seem to bear little relation to the present contour of the lakes, they at least show that the district was subject to dislocation and subsidence, and in this way relief may have been obtained from the earth-stresses which a few miles away to the east have caused pronounced folding in the Cretaceous limestones.

Beneath the basal conglomerates of this series lies an older system of rocks, which are well exposed on the promontories of the lake-shore, where they consist of false-bedded white and yellow quartzites, frequently containing bands of small white quartz-pebbles. They are strongly folded, but have a general dip of about 45° south-south-westwards (see fig. 3). Most of these beds appear to be unfossiliferous; but near the base occur black shales and a thickly-bedded, dark-grey, cherty limestone which yielded a scanty and badly-preserved fauna, comprising one or more species of brachiopods (*Terebratula*), gasteropods (*Nerinea*), and a lamellibranch (*Perna*). These remains were much silicified and difficult to extract, and they seemed to afford little clue as to their age. Mr. S. S. Buckman, however, has kindly examined some of the specimens for me, and reports that the Terebratulas almost certainly belong to the *perovalis* group, and, as such, indicate beds of Inferior Oolite age, *discites* zone.[1] The fragmentary

[1] Cf. *T. perovalis* Gottsche *non* Sowerby, pl. iv, fig. 9, 'Beiträge zur Geologie & Paläontologie der Argentinischen Republik' Palæontographica (1878), Naturgesch. der Vorwelt, Suppl. iii, Lief. ii, Heft 2.

remains of *Perna* he compares with specimens from the '*Witchellia*' Beds of Cold Comfort, near Cheltenham (*P. mytiloides* Bronn).[1]

In a palæontological map of Peru, recently published by Prof. Carlos Lisson, of Lima, a considerable area lying on the north-west of Puno is coloured as Lower and Middle Jurassic, from the reported occurrence, at a locality known as Compuesta, of an ammonite which he calls '*Reineckia anceps*.' This solitary piece of evidence, however, can hardly be deemed sufficient to warrant the mapping of so extensive an outcrop as that depicted. Most of this area is covered by transgressive Cretaceous deposits, and the specimen mentioned was probably obtained from the underlying Jurassic beds, which appear to be of somewhat limited extent.

Petrographical Notes.

(A 111) Basalt. Lagunillas.

Microscopic characters:—This rock contains idiomorphic phenocrysts and aggregates of smaller crystals of a colourless augite, showing twinning on the orthopinacoid, also zonary and hour-glass structure, with less abundant greenish-brown hornblende and brown biotite, both possessing well-marked resorption-borders.

The felspars do not occur as phenocrysts, and in this respect the rock has a certain resemblance to a basic lamprophyre.

The ferromagnesian phenocrysts are set in a fine-grained hyalopilitic ground-mass, composed of felspar-microlites (labradorite) with a more or less parallel arrangement in lines of flow, granules of augite, magnetite, and corroded flakes of biotite.

An olivine rich in iron (hyalosiderite), of a deep golden-brown colour, also occurs in sporadic crystals.

(A 112) Olivine-basalt. Saracocha. This rock occurs in the form of dark microcrystalline dykes cutting the limestone series on the shores of Lagunillas. It contains small phenocrysts of augite and brown pseudomorphs after olivine.

Microscopic characters:—Augite occurs in the form of relatively-large, pale-green, idiomorphic crystals, showing well-marked twinning and occasional zonary structure.

Large pseudomorphs with the characteristic outlines of olivine are also abundant. These consist of a network of fibrous serpentine, crowded with minute rhombs of calcite, and patches of a clear, colourless, isotropic mineral.

The felspar-crystals (basic labradorite) are confined to the ground-mass, which is holocrystalline and shows little or no trace of flow-structure.

It consists of minute, elongated, idiomorphic prisms of augite, larger lath-shaped crystals of labradorite, showing lamellar twinning and zonary structure, and frequent grains of magnetite; there is also much limonite in the more weathered portions, and an abundance of carbonates (calcite or magnesite).

From the Saracocha Lake to Santa Lucia, the structure of the country is somewhat obscured by a covering of volcanic tuff; but, as we approach Maravillas, an extensive development of pale-grey cherty limestone is again met with, being the continuation of the Cretaceous limestone-series of Lagunillas. In this district, however, the rocks have been strongly folded, and are penetrated by

[1] In R. I. Murchison, 'Geology of Cheltenham' 2nd ed. (1845) p. 76.

large intrusive masses of diorite. The diorite of Maravillas, both in petrographical characters and in mode of occurrence, is essentially similar to the rock previously described by me from Comanche in the Arica–La Paz section; moreover, though the country-rock is of an entirely different nature in the two areas (in the former case being a red sandstone, the 'Puca' sandstone of Steinmann), the intrusions are associated in both instances with productive copper-ores. We may reasonably conclude, then, that we are here dealing with the northward prolongation of that post-Cretaceous line of dioritic intrusion, which runs through Comanche and the Cerro de las Esmeraldas farther south in Bolivia; a line which is probably continued still farther northwards into the district drained by the Apurimac River.

It is interesting to note that the rocks in the immediate neighbourhood of the diorite do not appear to be cupriferous, and the mines are usually situated at some little distance from the actual contact. This fact has led some observers to regard the occurrence of the ore as being in no way connected with the igneous intrusion. After visiting both districts, however, I find it impossible to uphold such a theory.

The association of these rich copper deposits with the diorite is too striking to admit of any other explanation than that they were produced as a direct result of the intrusion; and, in view of the known distribution of the ore at some distance from the outcrop of plutonic rock, the absence of the latter from the mines of Coro Coro is an argument in favour of, rather than against, this theory: for, if we judge from the outcrops at Comanche and the Cerro de las Esmeraldas, we may reasonably infer that the diorite here lies at no great depth below the surface.

Although many of the mines have been worked ever since the time of the Spanish conquest, and in some cases previous to that date, the recent discovery of another rich ore-bearing district during the construction of the Arica–La Paz railway shows that the intervening country has not yet been thoroughly prospected with a proper appreciation of the facts.

(A 118) Diorite. Maravillas.

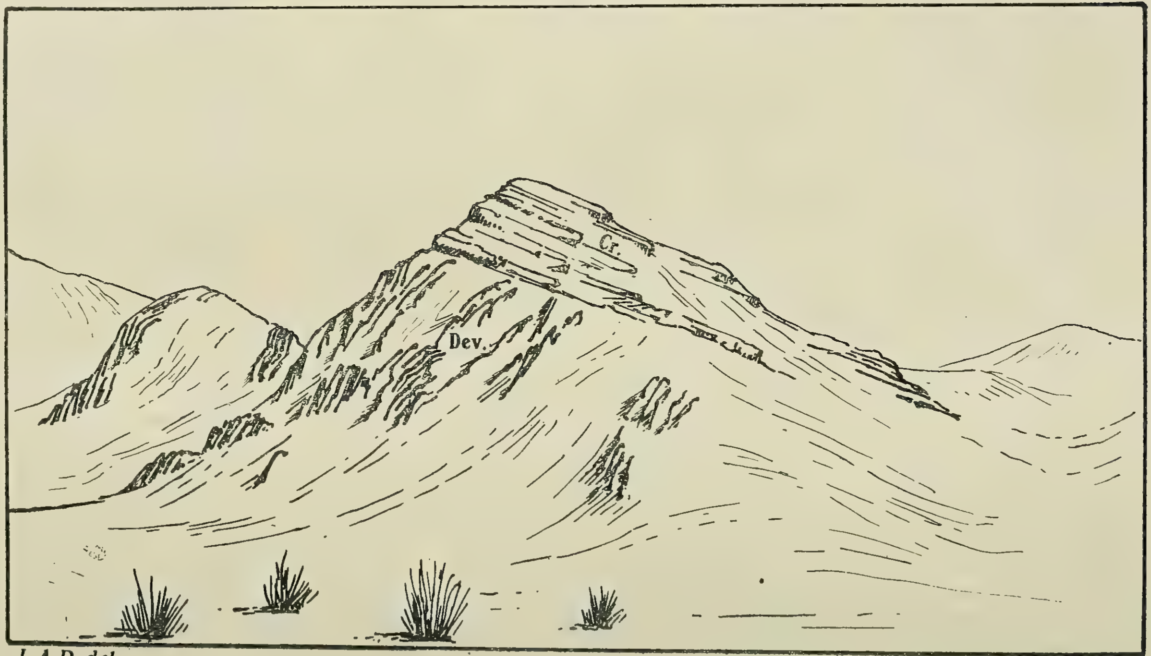
A grey holocrystalline rock of medium texture, almost identical in appearance with the Comanche diorite of Bolivia.[1] It consists essentially of white plagioclase and dark-green hornblende with, in the present case, a few flakes of biotite in addition to the latter. Small rounded patches of more basic composition, having the appearance of cognate xenoliths, are of common occurrence.

Microscopic characters:—A thin section of the rock, when viewed between crossed nicols, has a very peculiar appearance. This is due to the presence in great abundance of minute rounded and irregular grains of quartz, which seem to have been derived from the sedimentary rocks (chiefly Devonian quartzites), through which the dioritic magma has made its way towards the surface.

The plagioclase (an acid labradorite) shows little signs of alteration,

[1] See Q. J. G. S. vol. lxx (1914) p. 29 & pl. v.

Fig. 4.—*Cretaceous beds lying unconformably on steeply-inclined Devonian quartzites, Taya Taya.*



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and is remarkable for its pronounced zonary structure: a characteristic feature of the Comanche rock (see *op. cit.* pl. vii, fig. 5). It tends to be porphyritic in habit, having crystallized in general before the hornblende; numerous small crystals are also frequently enclosed in pœcilitic fashion by plates of the latter.

A yellowish-brown biotite is present, in addition to the green hornblende; they both show ragged outlines, and are but seldom idiomorphic. This, however, is a feature apparently due to subsequent partial solution in the magma, after they had assumed the crystalline form.

Magnetite is fairly abundant, and there is also a considerable amount of calcite.

Apatite occurs sparingly in small prisms.

Although the rock has undergone so profound a modification, all the essential underlying features of the Comanche diorite can at once be recognized.

The absorption of so large an amount of extraneous material would appear to suggest a batholitic mode of intrusion, rather than, as appears to be the case where it penetrates the Cretaceous limestones, one involving actual displacement of the strata. The latter rocks, however, are intensely folded, while the underlying Devonian quartzites, although dipping steeply, approach the diorite without any sign of such disturbance.

It is conceivable, then, that the magma gradually stoped its way by batholitic replacement through these ancient and resisting rocks, becoming much acidified in the process, and on reaching the overlying Cretaceous deposits, which, if we judge from the neighbouring districts, were at that time little folded, it encountered a less resistant mass capable of being removed from its path by the more drastic and rapid method of bodily displacement.

Much of the silica, derived according to this theory from the Devonian quartzites, must have become dissolved in the igneous magma, thereby rendering it increasingly acid, and causing a partial resorption of those minerals which had already begun to crystallize: of these the hornblende and biotite were most readily attacked, and their idiomorphic contours have been almost entirely destroyed.

Finally, the residue of the acidified magma consolidated as an intergrowth of quartz and plagioclase, the latter of a more acid variety than the phenocrysts. The rounded outlines of many of the quartz-grains, however, make it probable that they represent original sedimentary material that has been derived and corroded, but not fully dissolved.

The alluvial pampa of Maravillas ends in a somewhat narrow river-gorge, flanked on each side by cliffs of limestone and crimson marl; a short distance farther on, however, the valley once more expands to form the pampa of Taya Taya, and from this point to Lake Titicaca the fall of the river is very slight (about 1 in 1250).

On entering the pampa we meet for the first time with Palæozoic rocks. These are of Devonian age, and form an unbroken series on the north of the valley as far as Cabanillas, with an almost constant dip of 45° east-north-eastwards (see Pl. V).

On the south, however, the Cretaceous limestone continues as far as Taya Taya, where, capping the prominent escarpment behind the station, it rests with striking unconformity on the older series (see fig. 4, p. 34). The chocolate-coloured conglomerate of the Saracocha district is no longer represented: the basement-beds here consist of a white and pinkish quartzite-breccia, derived *in situ* from the underlying rocks.

In places, small isolated hills, with conspicuously rugged outline, mark the outcrop of the diorite.

The Devonian beds, which are almost bare of vegetation, are readily accessible by fording the river at Taya Taya, where they are found to consist of olive-green grits and sandstones and black ferruginous shales. Although for the greater part of their extent they appeared to be unfossiliferous, the shales opposite Las Huertas yielded a fairly prolific fauna.

The lowest beds are here crowded with crinoid-stems and the hollow casts of a bryozoan; these are succeeded by shales containing abundant brachiopods:—*Leptocœlia*, *Tropidoleptus*, *Spirifer*, *Chonetes*, etc., usually preserved in the form of casts. The highest beds of the series consist of black shales, with rounded concretionary nodules, which are highly fossiliferous, yielding several species of *Conularia*, and an occasional trilobite. Although many of the specimens recorded in the accompanying list, owing to their poor state of preservation, are of little value for the purposes of correlation or description, an analysis of the collective fauna clearly shows that these Devonian beds of Taya Taya correspond to the upper part of Steinmann's 'Icla Schiefer' of Bolivia, characterized by *Leptocœlia flabellites*; and, from the abundance of the genus *Conularia*, they may be considered as the equivalent of his '*Conularia*-Shales.'

Liorhynchus bodenbenderi, *Leptocœlia acutiplicata*, and *Scaphiocœlia boliviensis*, the forms characteristic of the Devonian beds of Coniri regarded by me as of Lower Devonian age, appear to be unrepresented in the district now described, and the continuation of these beds must be sought still farther west, where they are buried beneath the transgressive Cretaceous rocks. The Taya Taya beds, then, probably represent a somewhat higher horizon, and may be correlated with the *Marcellus* Shales, or lower division of the Middle Devonian Hamilton Group of North America.

FAUNAL LIST.

Orthoceras sp.
Bucaniella aff. *dereimsi* Knod.
Platyceras sp.
Nuculites sp.
Conularia africana Sharpe.
Conularia baini Ulrich.
Conularia quichua Ulrich.
Conularia acuta A. Rœmer.
Hyolithes sp.
Rhynchonella sp.
Tropidoleptus carinatus Conrad.
Spirifer aff. *mucronatus* Conrad.
Spirifer cf. *antarcticus* Morris & Sharpe.
Spirifer planoconvexus Knod.
Chonetes arcei Ulrich.
Chonetes aff. *coronata* Conrad.
Orthotetes cf. *chemungensis* Conrad.
Leptocœlia flabellites Conrad.
Dalmanites sp.
Phacops cf. *rana* Green.
Phacops aff. *schlotheimi* Kayser.
Proëtus sp.
Bryozoa and crinoids.

Palæontological Notes.

Conularia africana Sharpe. (Pl. I, fig. 1.)

This species, which was originally described by Sharpe from the Bokkeveld Beds of South Africa,[1] is characterized by the fact that the interspaces between the transverse ribs, in all states of preservation, are entirely devoid of any longitudinal striation. The smooth and somewhat pronounced transverse ribs are bent sharply towards the mouth, meeting along the median line on each side of the pyramid at an angle of about 120°. One specimen was obtained which showed that the ribbing is continued over the inner surface of the incurved lobes of the aperture.

This form has also been described from Bolivia by Ulrich.[2]

Conularia baini Ulrich. (Pl. I, fig. 2.)

Numerous examples of this species were obtained from the ferruginous nodules in the upper shales of Taya Taya, the reticulate appearance of its ornamentation readily distinguishing it from *C. africana*, with which form it has been confused by Knod.[3]

The transverse ribs, which curve towards the mouth and do not bear tubercles, are extremely fine in the young shell, but become coarser with increased growth; the somewhat sudden change is marked by the incoming of longitudinal ornamentation in the form of subordinate, flattened or gently-rounded ribs crossing the interspaces between the transverse ribs. The latter, however, are uninterrupted, except along the median line of each pyramid face, where a definite midrib occurs.

The longitudinal ribs are most marked towards the angles of the shell, and do not alternate in successive interspaces as in the North American form *C. huntiana* Hall,[4] being arranged as a linear sequence, resembling in this respect the type of ornament figured by Barrande as occurring in *C. proteica*.[5] *C. baini* was first described by Ulrich from Bolivia,[6] and was compared by him with *C. continens* var. *rudis* of Hall.

The Peruvian shells, however, show no signs of interlocking of the transverse ribs along the median line, a feature which appears to be characteristic of Hall's species.[7]

Conularia quichua Ulrich. (Pl. I, fig. 3.)

This typical South American species is characterized by its distinctive outline, and by the extremely fine nature of its ornament. The transverse ribs, which curve gently towards the mouth and are cut by a shallow median groove on each face, bear numerous small tubercles, due apparently to their intersection with the faint longitudinal striation. By abrasion of these tubercles each rib appears to be pierced by a single row of closely-set minute perforations.

A cross-section of the shell has the form of an elongate oval, and though this appears to be a constant feature, occurring both in our specimens and in those obtained by Ulrich from Bolivia,[8] it may possibly be due to deformation, consequent on the possession of an extremely thin shell which may have been sufficiently flexible to resist the fracture that has affected many of the more

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[1] Trans. Geol. Soc. ser. 2, vol. vii (1856) pl. xxvii, fig. 13.

[2] 'Paläozoische Versteinerungen aus Bolivien' Neues Jahrb. Beilageband viii (1892) p. 29 & pl. iii, fig. 4.

[3] 'Devonische Faunen Boliviens' Neues Jahrb. Beilageband xxv (1908) p. 516 & pl. xxiii, fig. 8.

[4] 'Natural History of New York: pt. vi, Palæontology' vol. iii (1861) pl. lxxii *a*, figs. 2 *a* & 2 *b*.

[5] 'Système Silurien de la Bohème' vol. iii (1867), Ptéropodes, pl. v, fig. 18.

[6] *Op. supra cit.* p. 36 & pl. iii, fig. 8.

[7] 'Nat. Hist. N.Y.—Pal.' vol. v, pt. ii (1879) pl. xxxiv *a*, figs. 7 & 8.

[8] *Op. supra cit.* p. 34 & pl. iii, figs. 7 *a* & 7 *b*.

stoutly-built forms. This species has also been described from the Argentine by Prof. E. Kayser,[1] and by Ivor Thomas.[2]

TROPIDOLEPTUS CARINATUS Conrad.

This species has now been shown by Henry S. Williams[3] to recur in three distinct horizons in the Portage and Chemung formations of New York; it can, therefore, no longer be regarded as a distinctive fossil of the Hamilton Shales.[4]

Beyond Cabanillas the Devonian strata dip steadily beneath the broad alluvial plains of Juliaca, which have been left by the gradual recession of the waters of Lake Titicaca, to reappear in the district north of the lake.

With the view, therefore, of obtaining further insight into the structure of the surrounding country, we decided to take the more direct route to Puno, and proceeded in a south-easterly direction from Las Huertas. Between this point and the hacienda of Yanarico, the transgressive Cretaceous beds are again seen resting on steeply-dipping Devonian quartzites. The country then becomes covered by large areas of swamp and tracts of alluvium, in such wise that its geological structure is almost entirely obscured.

Beyond Vilque, however, a new feature appears in the landscape, in the form of prominent flat-topped hills or 'buttes.' These were found to be due to the dissection of a thick horizontal sheet of lava, an olivine-basalt, which was traced nearly as far as Puno. Such an occurrence is of considerable interest, as being almost the only sign of volcanic activity in this inter-Andean region, comparable with the great outbursts which have built up the lofty peaks of the Western Cordillera.

The vesicular nature of the lava and its wide lateral extent suggest that it was extruded in the form of a fissure-eruption, which spread far over the surface of the surrounding country. Its undisturbed horizontality, when we consider the post-Cretaceous folding that has affected the district, shows that its formation must be of comparatively recent date.

No trace of feeders was detected in the immediate neighbourhood; but this is not surprising, as the slopes of the hills are everywhere covered by talus and vegetation.

(A 120) Olivine-basalt. Tiquillaca.

A highly-vesicular greyish-brown lava showing occasional flakes of biotite.

Microscopic characters:—In mineral composition it exhibits a marked similarity to the basaltic dykes which have been described above as cutting the Jurassic rocks of Lagunillas, and the microscopic structural differences are only such as can be explained by the different conditions

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[1] Zeitschr. Deutsch. Geol. Gesellsch. vol. xlix (1897) p. 288 & pl. xi, figs. 1 & 2.

[2] *Ibid.* vol. lvii (1905) p. 254 & pl. xii, fig. 19

[3] 'Recurrent *Tropidoleptus* Zones of the Upper Devonian in New York' U.S. Geol. Surv. Prof. Paper 79 (1913).

[4] For a comparison with *Tropidoleptus fascifer* Kayser, see 'El Devoniano de la Argentina Occidental' by Dr. J. M. Clarke, pp. 6–7: Anales del Ministerio de Agricultura, Republica Argentina, Seccion Geologia, etc. vol. viii (1912) No. 2.

under which the rocks have consolidated. The greater freedom of movement in the present case has hindered the ready growth of porphyritic crystals.

The phenocrysts of augite, seen in A 112, are here represented by granular aggregates, which in some instances show that they originated by the breaking-up of a larger crystal.

Porphyritic flakes of biotite are not uncommon, the presence of this mineral possibly being dependent on the relatively low temperature of consolidation.

An iron-rich olivine, altering to a yellowish-brown iron-oxide, is also present in some abundance, with an occasional trace of the original mineral still apparent.

The ground-mass consists of granules and prisms of a faintly-coloured augite, irregular grains of magnetite, and minute laths of felspar with pronounced flow-structure.

(3) The Geological Structure of the Country between Tirapata and the Inambari River.

After completing the first half of our section at Puno, we proceeded northwards, along the strike, to the village of Tirapata, in order to gain access to the interior or 'Montaña' region. The geological structure of the intervening country is for the greater part concealed beneath the wide alluvial flats, formerly covered by the waters of Lake Titicaca. In places, however, outcrops of the underlying rocks are met with, and a connexion between the two halves of the section can thus be established.

About a mile south of Puno, in a small quarry on the shores of the lake, is seen an unfossiliferous grey limestone with a dip of 45° south-south-westwards; this was found to overlie a thick series of red sandstones and conglomerates, which were traced along the south-western shore of the lake as far as the village of Pomata.

On proceeding northwards from Puno along the trail to Juliaca, we again meet with grey dolomitic limestones, red shales, sandstones, and conglomerates, cropping out from beneath the sheet of vesicular olivine-basalt of Tiquillaca, while beds of white quartzite are exposed in a small ravine leading down to the railway-line. Limestone again appears at the little village of Caracoto, and red sandstone at the station of Juliaca.

Thus far we have been dealing solely with lithological characters, for no palæontological evidence was obtained from this area.

In general appearance, however, these rocks are totally unlike those in the neighbouring districts known to contain Devonian fossils, and as they bear a marked resemblance to the Upper Carboniferous or Permo-Carboniferous series, previously described from the Copacabana peninsula and the district east of Comanche in Bolivia, which lie along the same line of strike, they are provisionally regarded as being of the same age as the latter.

(Prof. Lisson, in a summary of the distribution of the fossiliferous deposits of Peru, describes a small collection of Devonian fossils, preserved in the museum of the School of Mines at Lima, said to come from the neighbourhood of Puno; no exact locality is recorded,

however, and it is more than likely that they were obtained from the Devonian beds between Puno and Taya Taya. The following forms are mentioned:—*Cryphæus convexus* Ulrich, *Platyceras* sp., *Spirifer planoconvexus* Knod, *Lyopora gigantea* Knod, and crinoid-remains.)

Continuing northwards, we meet with a further series of beds between Juliaca and Laro, apparently distinct from those above enumerated, comprising olive-green quartzites, shales, and sandstones, which have a more or less constant dip in a south-westerly direction. These are very similar in appearance to the Devonian beds of Taya Taya; and, in fact, a short distance farther east, between Pusi and Taraco, the following fossils have been recorded by Señores Dueñas & Romaña:—*Phacops* cf. *dagincourti* Ulrich, *Orthoceras* sp., *Conularia* sp., *Tentaculites* sp., and *Tropidoleptus carinatus* Conrad.

An identical fauna has also been obtained from the neighbourhood of Sicuani, a village still farther north on the line to Cuzco; and, as Tirapata lies directly between these two points, the barren shales and shaly sandstones which are found at this locality are regarded on both stratigraphical and lithological grounds as being of the same age.

If we proceed, moreover, along the same line of strike far towards the south-east, we eventually reach the Devonian area of Tiahuanaco and Coniri in Bolivia.

It will thus be seen that, although I rely in great part on the lithological characters of the rocks in the determination of their age, the conclusions arrived at are in no way contradicted by the meagre palæontological evidence obtained at one or two isolated localities.

As we continue our journey north-eastwards from Tirapata, the Devonian shales and impure sandstones are no longer inclined towards the south-west, but are seen to dip in an easterly direction beneath a strongly-folded series of grey limestones, dolomites, red marls, and white quartzites. These rocks are well exposed along the road to Progreso, and on the southern shore of the lake beyond Asillo.

At the hamlet of Recreo the trail turns northwards, following the strike of the folds up a small river-valley cut along one of the anticlinal axes. The beds here consist chiefly of conglomerates and sandstones, with an occasional prominent band of grey limestone.

The river has its origin in a small lake (Lago Cerera), at the far end of which we traverse the actual core of the anticline, here seen to be formed of limestone overlain on the east by conglomerate dipping 30° north-eastwards.

This whole series of rocks, although well exposed and freely accessible, failed to reveal any trace of fossils; but there can be little doubt that it represents the northward continuation of the Carboniferous series of the isthmus of Copacabana and the Island of the Sun in Lake Titicaca.

Both the geological structure of the country and the lithological character of the beds are almost sufficient to warrant this conclusion; but more convincing proof was fortunately obtained, in the form of palæontological evidence, a few miles farther north in a little valley known as Viscachani.

A short distance beyond the lake lies the disused Indian chapel of Santa Isabel, and in the bed of the stream at this point appear beds of red shaly sandstone showing beautiful ripple-marking; these have a steep dip of about 80° south-south-westwards, and, although their junction with the overlying beds is not visible, they appear to belong to an older series (probably of Devonian age, being very similar to the red shales of Tirapata).

The valley of Viscachani is flanked on the west by a steep escarpment of grey limestone, the continuation of that seen in the valley above Recreo. This was found to overlie a purple limestone series which yielded fossils in some abundance.

The late Dr. Arthur Vaughan, having looked through the specimens obtained from this locality, gave it as his opinion that they represent a fauna indicative of the very top of the Lower Carboniferous or Avonian sequence, corresponding to the *Cyathaxonia* Beds (D 2–3) immediately below the Pendleside of the Midlands. They may thus be regarded as being from a somewhat lower horizon than the fauna previously described by me from the Copacabana peninsula, which was shown to be of Upper Carboniferous or of Permo-Carboniferous age.

The more important index-fossils were starred by Dr. Vaughan, and on these his determination was based; but it must be noted that he had no opportunity of examining the sections of corals, which were not cut until the present year. Although these, for the greater part, belong to new or little-known types, it is interesting to find that they in no way negative his conclusions, which are further supported by stratigraphical considerations, for the limestones of the Titicaca district overlie the beds here described.

FAUNAL LIST.

Productus aff. *semireticulatus* Martin.
Productus aff. *cora* D'Orbigny.
**Productus* aff. *longispinus* Sowerby.
Rhipidomella aff. *michelini* (L'Éveillé).
**Spirifer bisulcatus* Sowerby.
Spiriferina aff. *cristata* Schlotheim.
**Reticularia lineata* (Martin).
**Ambocœlia urii* (Fleming).
Seminula aff. *ambigua* (Sowerby).
**Retzia radialis* Phillips.

Euomphalus sp.
Pleurotomaria sp.

Edmondia sp.

Fenestella sp.
Fistulipora aff. *incrustans* (Phillips).

**Cyathaxonia* aff. *rushiana* Vaughan.
Cyathaxonid (cf. *Cyathaxonia* aff. *costata* M'Coy, Vaughan: figured in Q. J. G. S. vol. lxii, 1906, pl. xxix, fig. 5).
Zaphrentis aff. *enniskilleni* Milne Edwards & Haime.
Lophophylloid *Zaphrentis*.
Lophophylloid *Caninia* (cf. *Caninia cornucopiæ* Michelin, Carruthers).
Zaphrentis aff. *eruca* (M'Coy).

A study of the faunal assemblage enumerated in the above list shows that many of the leading coral groups, characteristic of the

Viséan of Europe (as, for example, *Lithostrotion* and the Clisiophyllids), are entirely unrepresented. Its most remarkable feature is the abundance of small Zaphrentid corals showing a certain degree of resemblance to *Lophophyllum* and *Cyathaxonia*.

Since some confusion still appears to exist as to the exact limitations of these genera, I have added a short discussion on their relationship with the forms here described.

Palæontological Notes.

Of the specimens which I have termed Lophophylloid Zaphrentids many appear to be closely related to the corals figured and described as *Lophophyllum* by Thomson & Nicholson in 1876,[1] agreeing with them in general size and form, in the absence of any external zone of vesicular tissue, and in the possession of a longitudinally-ribbed epitheca and a clavate columella joined at one extremity with a single septum. The latter, however, was described as lying within the septal fossula, whereas in the present case it is invariably the counter-septum that is elongated.

Although classed as Lophophylla, their relationship with *Zaphrentis* is admitted: the only essential point of difference being the presence of a 'central columellar eminence.'

Of late years, Mr. R. G. Carruthers has shown, from an examination of Belgian topotypes, that the genotype of *Lophophyllum* (*L. konincki* Edwards & Haime) had a smooth epitheca, and is synonymous with *Cyathaxonia tortuosa* of Michelin. In the absence of the original holotypes, *Lophophyllum tortuosum*, as redefined by Mr. Carruthers, must, therefore, be taken as the type, and the forms described by Thomson & Nicholson can no longer be referred to this genus, which differs from them in possessing a smooth epitheca, well-developed minor septa, and a zone of dissepiments.

If Vaughan was correct in assigning the fauna here described to the extreme summit of the Avonian sequence, these corals cannot be considered as phylogenetically intermediate between *Zaphrentis* and *Lophophyllum*: for, according to Mr. Carruthers, the latter genus is already typically developed in the Tournaisian, whereas *Zaphrentis* does not approach extinction until the close of Avonian time. It is equally impossible to regard these Zaphrentid corals as derived from a Lophophylloid ancestor. Any tendency in one or other of the two forms towards the development of a similarity of structure must, therefore, be ascribed to convergence or coeval assimilation.

Mr. Carruthers has recently given an instructive description of the evolution of *Zaphrentis delanouei*: and some of the later members of that gens, predominant in the Upper Limestone Group and Millstone Grit of Scotland, show in their ephebic stages a marked resemblance to the forms described here. A comparison,

[1] Ann. & Mag. Nat. Hist. ser. 4, vol. xvii (1876) pp. 126-28 & pl. viii, figs. 3-7.

for example, of the specimen shown in Pl. I, fig. 8, with *Zaphrentis disjuncta* as figured by Mr. Carruthers,[1] shows that the two possess the following features in common:—Longitudinal ribbing of the epitheca; cardinal fossula on the concave side of the corallum; 22 major septa; septa Amplexoid, thickened at their inner ends, and convex to the cardinal fossula; no minor septa; simple tabulæ.

The development of Amplexoid septa in a late stage of the phylogenetic history of the gens must necessarily have seriously lessened the structural strength of the corallum, and the lengthening of one of the septa, in this case the counter-septum (which, from its position, is naturally most fitted for the purpose), to form a central plate thickened at its end into a rod-like columella, would materially aid in counteracting any such weakness. It is possible, then, that the extinction of the *delanouei* gens, foreshadowed by this catagenesis or simplification of structure, may have been delayed by the acquisition of a Lophophylloid columella.

The causes of variation are too little known to admit of an adequate proof of such a theory; but the phenomenon of parallel development in many Avonian corals suggests that these forms of life were readily adaptable to external conditions.

Perspecialization in any gens is characteristic of the stage immediately prior to extinction, when its capacity for survival is limited by its power to change; and this doubtless is largely influenced by environment, migration to new surroundings tending to give a new lease of life.

It might reasonably be argued, however, that the extension of the counter-septum more than half-way across the corallum may be taken to imply the retention of a primitive character rather than the acquisition of a new one, for in the protoseptal stage of the Rugosa the cardinal and counter-septa are continuous one with the other, and the point of separation need not necessarily be central, a feature often seen in such forms as *Caninia cornucopiæ* and *Zaphrentis omaliusi*. It is the secondary thickening of the counter-septum, however, rather than its length, that is the chief factor in forming the columella, and a study of the ontogenetic development of the coral, made by grinding down a number of individual specimens, shows that its special modification for this purpose does not take place until a comparatively late stage of growth, when the septal plan is already well established. The central rod-like columella, moreover, often almost circular in cross-section, appears in some cases to be added to the extreme tip of the counter-septum, while in others it is formed by lateral thickening.

In discussing the question of convergence or coeval assimilation, it is not without significance that several of the corals here described, which possess in common this feature of an extended and swollen counter-septum, differ one from the other in other points of structure, and appear to have been derived, if not from different genera, at least from different species-groups. If, then, I have

[1] Q. J. G. S. vol. lxvi (1910) pl. xxxvii, fig. 7*a*.

not attached undue importance to this modification of structure, it may be said that the dominant 'tone' of the age was Lophophylloid.

In the absence of any known Lower Avonian corals from South America, a direct descent from a true Zaphrentid ancestor along any known gens-line cannot at present be definitely proved. It has not been thought advisable, however, to institute distinctive generic names for these new forms until such a possibility is denied. I have, therefore, restricted myself to the use of such terms as 'Lophophylloid *Zaphrentis*,' thereby implying a coral having the typical structure of a *Zaphrentis* combined with an essentially Lophophylloid columella, which, unlike that of a *Cyathaxonia*, is a direct continuation of the counter-septum. The relationship of any of these forms with *Cyathaxonia* is more superficial than real, although an occasional individual section may reveal a disposition of septa suggestive of a Cyathaxonid type of structure.

In one example (Pl. I, figs. 9*a*–9*e*) the inner ends of the septa are fused with a thick stereoplasmic lining, the continuity of which is broken by the cardinal and alar fossulæ.

In earlier stages of growth, however, increased thickening often results in the formation of a confused central mass, the nature of which is not apparent until further sections are cut from the same specimen. The columellar thickening of the counter-septum and the club-shaped extremities of the other major septa are then seen to have their origin in this stereoplasmic lining, and, where the latter wraps round the ends of the septa without forming complete contact, a series of hollow terminal tubes is produced.

It thus becomes apparent that, although the final result attained (an increase of strength in the corallum) is the same in many cases, homogenesis of structure must by no means be taken for granted.

Lophophylloid Zaphrentis. (Pl. I, figs. 8*a*–8*f*, 9*a*–9*e*.)

Description.—Corallum simple, conical and cornute. Epitheca strongly costate: alternate sulci corresponding to internal septa. Floor of calyx radiated by a single series of 22 well-spaced major septa. Cardinal septum short, situated on the concave side of the corallum. Fossular depression ill-defined.

Counter-septum long, extending to the centre of the corallum, and thickened at its inner end to form a laterally-compressed plate-like columella.

Horizontal sections.—In the earlier stages of growth the septa are distinctly Zaphrentid in character, the cardinal and alar breaks being well-defined. The septa are considerably thickened, and show a curvature convex to the cardinal fossula. The latter is at first wide, narrowing inwardly, but in the adolescent stage, owing to the growth of new septa in the cardinal quadrants, becomes somewhat constricted at its centre (fig. 8*d*). In the mature stage, the septa, with the exception of the counter-septum, are thin and Amplexoid in character, having become entirely separated at the centre of the corallum. The cardinal fossula is inconspicuous, being indicated merely by a shortened septum.

Minor septa are absent or undeveloped. Tabular intersections are rare.

Vertical section.—Tabulæ are seen to be few in number and widely spaced (fig. 8*f*). They are gently arched towards the calyx, and dip some-

what steeply into the cardinal fossula, which extends to the centre of the corallum, and is penetrated by the counter-septum.

Affinities.—This form appears to be closely related to *Zaphrentis disjuncta* Carruthers,[1] the points of resemblance having been noted above.

LOPHOPHYLLOID CANINIA. (Pl. I, figs. 7 *a*–7 *c*.)

Description.—Corallum cylindro-conical; variable in shape; often showing marked irregularities of growth. Epitheca thin and smooth, but occasionally bearing traces of longitudinal ribbing.

Horizontal sections.—Major septa irregular, with radial disposition; slightly thickened at their inner ends; Amplexoid in character from an early stage, leaving a central tabulate area penetrated only by the counter-septum, which is elongated and thickened to form a central columellar plate. Cardinal septum short. Fossula indistinct, usually bounded by the intersection of a tabula with the plane of section.

Minor septa absent or undeveloped. Tabulæ few in number, somewhat irregular and widely spaced. No marginal dissepimental zone.

Affinities.—This form in its general septal development and irregularity of growth appears to be more nearly related to *Caninia* than to the Zaphrentids. It differs from *Caninia cornucopiæ* Michelin emend. Carruthers (Geol. Mag. 1908, p. 158) chiefly in the less numerous major septa, and by the absence in all stages of growth of minor septa and an external zone of dissepiments. In these respects it bears considerable resemblance to *Zaphrentis amplexoides* Wilmore.[2]

ZAPHRENTIS aff. ERUCA (M'Coy). (Pl. I, fig. 5.)

Description.—Corallum simple, conical, slightly cornute. Epitheca strongly costate. Major septa, 22 in number, straight and slightly swollen at their inner extremities; radial in disposition and becoming Amplexoid at an early stage of growth.

Counter-septum long, extending more than half-way across the corallum; laterally thickened at its end to form a clavate columella. Cardinal fossula inconspicuous, the break being indicated by a shortened septum. Tabular intersections very regular and evenly spaced. Outer wall thick, but showing no trace of minor septa. No marginal zone of dissepiments.

Affinities.—This form agrees closely with *Cyathopsis eruca* of M'Coy.[3] The genus '*Cyathopsis*,' founded by A. d'Orbigny for corals resembling *Amplexus* but possessing a septal fossula, is, however, an unsatisfactory one, and the species was redescribed and figured as a *Lophophyllum* by Thomson & Nicholson.[4] Mr. R. G. Carruthers has shown that it can no longer be referred to that genus; and, until more light can be thrown on the phylogeny of this and kindred species, it may be regarded as an Amplexoid *Zaphrentis* possessing a Lophophylloid type of columella.

In the possession of a strongly-costate epitheca, in the radiate arrangement of the septa, and in the regularity of the tabular intersections, it shows a close affinity with *Cyathaxonia costata* M'Coy, as figured by Vaughan[5]; the latter species, however, has now been assigned to the genus *Lophophyllum* by Dr. A. Wilmore,[6] although it appears to be doubtful whether that author is justified in regarding the forms discovered by him in the Craven district as identical with that figured by Vaughan, for the latter species is described as having a strongly-costate epitheca, and is apparently devoid of minor septa.

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[1] Q. J. G. S. vol. lxvi (1910) p. 534 & pl. xxxvii, figs. 6 *a*–8 *d*.

[2] *Ibid.* pl. xxxviii, figs. 1–9.

[3] Ann. & Mag. Nat. Hist. ser. 2, vol. vii (1851) p. 167.

[4] *Ibid.* ser. 4, vol. xvii (1876) pl. viii, fig. 7*a*.

[5] Q. J. G. S. vol. lxii (1906) pl. xxix, fig. 5.

[6] *Ibid.* vol. lxvi (1910) p. 573.

CYATHAXONIA sp. (Pl. I, figs. 4 *a* & 4 *b*.)

Description.—Corallum simple, conical, slightly cornute. Epitheca strongly costate. Eighteen major septa, radially disposed, and of more or less equal length; slightly swollen at their inner extremities. These alternate with a series of minor septa, two of which (the fourth from the cardinal septum on each side) are more pronounced than the others.

The centre of the corallum is occupied by a rod-like columella, oval in cross-section, which appears to be a structure independent of the septa. In the earlier stages of growth the ends of the major septa are fused to it, and at first sight seem to take part in its construction. In some cases, however, the central core has been dissolved away, leaving a hollow tube, and thereby disclosing its true character. In the mature stages the counter-septum alone remains attached, its continuation through the solid axis being disproved by the absence of any trace of a mesial line.

The structure of the columella, therefore, is distinctly Cyathaxonid in character, for it has clearly not been formed, as in the Lophophylla, by the upward growth and thickening of the counter-septum. A fossular break is merely indicated by a shortened cardinal septum. No trace of tabular intersections were observed.

Affinities.—The Cyathaxonid type of columella, the presence of minor septa, and the apparent lack of tabulæ, readily distinguish this form from any of the preceding. The solidity of the central axis, and the strongly-costate epitheca, suggest that it is closely related to *Cyathaxonia costata* M'Coy, the relationship of which with the Densiphylloid Zaphrentes has already been noted by Vaughan.[1] In the earlier stages of its growth it shows a certain resemblance to *Carcinophyllum simplex* Garwood,[2] but differs from that form in its small size, less number of major septa, and the absence of any peripheral dissepimental zone.

ZAPHRENTIS aff. ENNISKILLENI Edwards & Haime. (Pl. I, figs. 6 *a* & 6 *b*.)

Description.—Corallum conical, cornute. Epitheca smooth, with annular striations. Cardinal fossula deep, extending to the centre of the corallum; situated on the concave side; narrow, and with almost parallel sides; widening slightly towards the wall, the expansion becoming more pronounced in sections near the calyx. Position of alar fossulæ clearly defined by a septal break and discontinuity of tabular intersections. Major septa, 35 in adult, strongly thickened, especially in the anti-fossular group; their inner ends are coalescent in the younger stages of growth. Cardinal septum very short. Curvature of the septa convex to the cardinal fossula, ill-defined in youth but becoming pronounced in the adult. Minor septa absent or undeveloped. Tabulæ few in number and evenly spaced.

Affinities.—This form appears to be a typical representative of the '*Enniskilleni*' gens, differing from the type chiefly in the absence of minor septa. In the character of the fossula, the number and disposition of the septa, and the thickening of the counter-septum, it most nearly approaches the form figured by Vaughan from the *Posidonomya* Beds of Loughshinny.[3]

The limestone of the Viscachani district, as has been mentioned above, is divisible into an upper grey cherty limestone and a lower purple limestone, the latter being largely composed of fragmentary crinoid-remains. With the exception of *Zaphrentis* aff. *enniskilleni* and *Productus* aff. *cora*, all the forms mentioned in the faunal list on p. 41 appear to be restricted to the lower beds; and, since the lithological change is also accompanied by a slight discordance in the dip, it is possible that a gap in the sequence

[1] Q. J. G. S. vol. lxii (1906) p. 318.
[2] *Ibid.* vol. lxviii (1912) p. 556 & pl. xlviii, figs. 3*a*–3*c*.
[3] *Ibid.* vol. lxiv (1908) pl. xlix, fig. 13.

is indicated. A comparison of the faunal list given here with that of the limestone of the Titicaca district[1] further bears out this suggestion, for only one or two species are common to both.

The basement-beds are seen to rest with a well-marked unconformity on an older series of rocks, comprising olive-green sandstones, quartzites, and black shales with concretionary limestone-bands. These beds are strongly folded, the dip in places being nearly vertical, and, if we judge from the frequent discordance in their strike, they appear to have been much faulted, as shown in the accompanying sketch-map (fig. 5, p. 48). With the exception of countless worm-tracks and a single obscure specimen of a lamellibranch shell, they proved to be unfossiliferous. Their lithological character suggests that they are of Devonian age, but it was not considered advisable to separate them definitely from the older Palæozoic rocks with which they are continuous.

The latter, comprising hard grits, greywackes, and dark slates, when first met with have a more or less constant dip westwards, but at the summit of the Quellosani Pass they are inclined in a north-easterly direction, and between this point and Macusani they are much folded. In general appearance these beds closely resemble the ancient rocks of the Pongo Valley, on the eastern slopes of the Bolivian Cordillera, which are regarded as being of Silurian or even earlier age; and they are grouped together here, tentatively, as Lower Palæozoic, for fossiliferous beds of similar character were met with farther east.

A short distance beyond Macusani commences the descent of the San Gaban river-gorge, and one immediately encounters a remarkable suite of igneous rocks which differ totally in character from those described above as forming the plutonic core of the Western Cordillera. With these are associated wide tracts of schistose rocks presenting the appearance of highly-altered sediments, while the igneous rocks themselves locally show signs of intense crushing with the production of gneissic structure. The district is one that has evidently undergone profound dynamic metamorphism; but, as the Cordillera has been subjected to more than one period of orogenic movement, it is difficult to say to which of these such a result should be attributed. I can see no valid reason for supposing these rocks to be of earlier date than the fossiliferous Lower Palæozoic rocks found still farther east, and I am tempted to regard them as constituting an ancient resistant horst formed during the period represented by the gap between Middle Devonian and Upper Avonian deposits, and thus as having played an important part in determining the structural features produced during subsequent folding of the Cordillera.

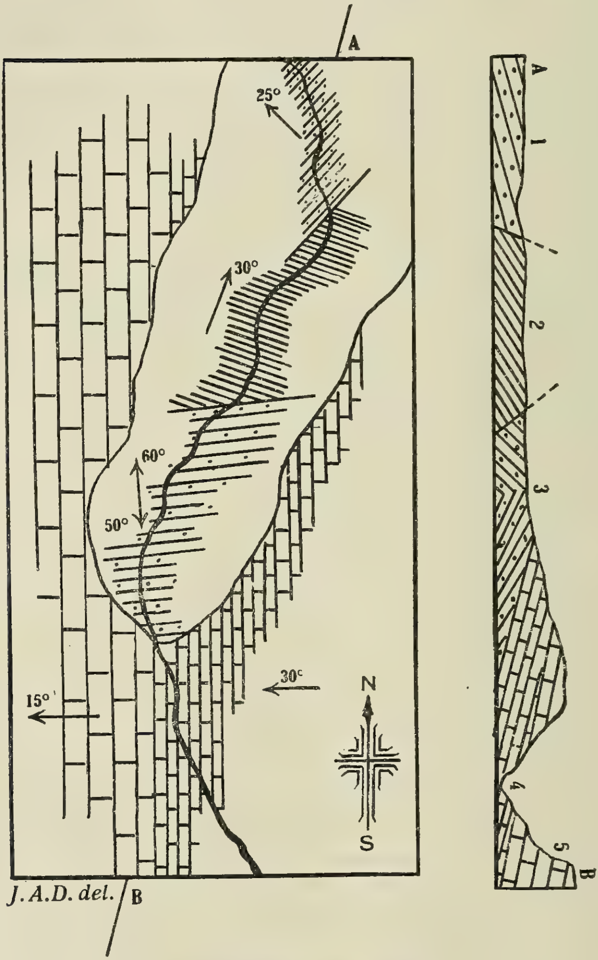
The evidence on which this assumption is based, however, is too slight to be in any way conclusive, and it is given here merely in the light of a suggestion for future work.

At the head of the San Gaban gorge, a short distance beyond

[1] Q. J. G. S. vol. lxx (1914) p. 31.

Quencha, beds of white quartzite, dipping 20° north-north-eastwards, are seen cropping out on the right of the valley. They

Fig. 5.—*Geological sketch-map of the Viscachani Valley, showing unconformity of Carboniferous Limestone on older Palæozoic rocks.*



[Approximate scale, 1 : 4000.]

1 & 3 = Olive-green quartzites. 2 = Black shales. 4 = Purple limestone with Zaphrentids. 5 = Grey limestone.

show no signs of the intense crushing exhibited by the underlying rocks; and, although the actual junction of the two is not visible, it is obvious that they are of later date than these. The

only other rock of like character that I have come across in the whole district is a white quartzite from the Carboniferous Series in the neighbourhood of Puno, and I know of no record of beds of later age than this occurring on the eastern slopes of the Cordillera in this latitude.

The sides of the river-valley almost as far as Ollachea are formed of a coarse elæolite-syenite porphyry of very distinctive character. It is a handsome rock, composed of large, grey, porphyritic crystals of anorthoclase and elæolite, set in a black or dark-grey microcrystalline ground-mass. Locally it has been subjected to intense dynamic metamorphism, and has been transformed into a banded gneiss. The conspicuous phenocrysts normally show no definite arrangement; but, where pressure has affected the rock, they assume a roughly-parallel direction, individual crystals being crushed and sheared in the process, first into elongate lenticles, and finally into long drawn-out lines.

The change, as seen macroscopically, is almost identical with that described by Prof. H. J. Seymour[1] in the progressive dynamo-metamorphism of a porphyritic andesite from County Wicklow, the result in each case being a banded rock in which original ground-mass and phenocrysts have given rise respectively to alternating dark and light bands.

Owing to the inaccessible nature of the gorge, the tectonic relations of this rock are not clear; but it appears to be intrusive into the slates and metamorphic schists which succeed it lower down the valley.

A short distance above Ollachea hot springs issue on the left of the valley, and deposits of siliceous sinter are being formed in small though well-defined terraces. Near this point other and distinct intrusions of plutonic rock are met with, in the form of augite- and elæolite-syenites. The former is almost identical in a hand-specimen with certain essexites, but microscopically it is seen to be more closely related to a syenite of the laurvikite type. The elæolite-rock, in which the coloured minerals are only subordinate, closely resembles foyaite.

Both of these intrusions appear to be of later date than the elæolite-syenite porphyry mentioned above, for, microscopically at least, they show no signs of having been subjected to dynamic action. This whole suite of igneous rocks is of typical 'alkaline' facies, and may be regarded as forming part of the great Brazilian province, which is thus shown to extend, as indeed might have been expected on *a priori* grounds, to the very flanks of the folded chains.

Sedimentary rocks, comprising dark slates and phyllites, are met with for the first time in the immediate neighbourhood of Ollachea, and when these are followed down the valley they are seen to pass into biotite-schists containing abundant rose-pink crystals of andalusite.

[1] Sci. Proc. Royal Dublin Soc. n. s. vol. xi, pt. 5 (1902) p. 568

We now begin to enter the densely-forested region of the Montaña, and any attempt to determine the relations between individual rock-exposures becomes well-nigh impossible.

The metamorphic schists, however, can be more or less continuously followed as far as Casahuiri, varying in character from time to time according to their original arenaceous or argillaceous nature. Here they once more pass gradually into phyllites, slates, and relatively unaltered sediments.

Midway between Ollachea and Urahuasi is exposed a large surface of rock having the appearance of a fault-plane: this dips steeply southwards, and breaks across the planes of schistosity, which at this point are inclined in exactly the opposite direction. Below Urahuasi Bridge further outcrops of plutonic rock are encountered which have the composition of a mica-syenite or durbachite. Locally traces of gneissic structure are visible, but the rock has evidently not shared to the full extent the dynamic metamorphism to which the older rocks of the district have been subjected.

Between Llinquipata and Puerto Seddon are numerous roadside exposures of more or less unaltered sedimentary rocks, chiefly in the form of black friable shales containing auriferous quartz-veins. They are, as a rule, highly contorted, but have a fairly-constant strike east-south-eastwards. Although these were closely examined in an attempt to determine their age, no trace of fossils was discovered until we reached the tributary valley of the Chaquimayo River, where the waterworn pebbles and boulders of the stream-bed were found to contain graptolites in some abundance.

The bed-rock is here almost entirely concealed from view beneath a thick clothing of tropical vegetation, and, although by following the valley to its source, occasional specimens were obtained *in situ*, no zonal sequence of the beds could be established. I am much indebted to the late Prof. Charles Lapworth for making a report on the graptolites from this locality, and he had very kindly proposed to publish this in the form of an appendix to the present paper. The fauna is essentially similar to that obtained by Dr. J. W. Evans from the Caupolican district of Bolivia, and was shown by Prof. Lapworth to be of Llanvirn age.

Faunal List.

Loganograptus logani Hall.
Goniograptus sp. nov.
Didymograptus bifidus Hall, var.
Didymograptus stabilis Elles & Wood.
Phyllograptus angustifolius Hall.
Glossograptus acanthus Elles & Wood.
Cryptograptus tricornis Hall, var.
Amplexograptus confertus Lapworth.
Amplexograptus cœlatus Lapworth.

Petrographical Notes.

A 121. Elæolite-syenite porphyry. Rio San Gaban.

A coarsely-porphyritic rock, of which the phenocrysts form nearly half the bulk. These consist of greenish-grey elæolite, showing hexagonal and

rectangular cross-sections, and a grey anorthoclase with characteristic rhomb-shaped outlines. The two minerals are not easily distinguished one from the other, except for the cleavage-faces of the felspar. The ground-mass is microcrystalline, and usually black or dark grey. Where it has undergone crushing, however, it frequently assumes a red or green tint.

Microscopic characters.—Large porphyritic crystals of felspar and elæolite are present in about equal proportions. The former (anorthoclase), showing microperthitic intergrowths, are slightly cloudy through decomposition, and include numerous prismatic crystals of elæolite. The larger phenocrysts of elæolite are irregularly cracked, and though glassy-clear in ordinary light, are seen, between crossed nicols, to have undergone considerable alteration; resulting in confused flaky aggregates of brilliantly-polarizing colourless mica (probably gieseckite).

Smaller crystals of a pale-green augite are present in some abundance, and more sparingly olivine in rounded grains with dense magnetite-rims. Apatite occurs as inclusions in the augite.

The holocrystalline fine-grained ground-mass is composed of minute prisms of augite, felspar-laths with straight extinction, abundant grains of magnetite, and a second generation of elæolite, the low double refraction of which causes it at first sight to appear isotropic.

In the crushed and banded rock the structure of the ground-mass has been almost obliterated, while porphyritic crystals remain for a time as uncrushed 'eyes' in the mylonitic matrix. With further crushing these also become ground down and drawn out into elongated lenticles.

The felspar-crystals show all the phenomena of mechanical deformation, the cracks in many cases being filled up with secondary growths of felspar substance. The original inclusions of elæolite have been converted into a colourless isotropic mineral, presenting the appearance of sodalite, and the same mineral has been produced (together with flaky aggregates of white mica) at the expense of the larger phenocrysts.

Lenticular patches composed entirely of serpentine and calcite represent original crystals of pyroxene.

A fine-grained quartz-felspar mosaic is characteristic of the final stages of crushing.

A 123. Elæolite-syenite. Ollachea.

A pinkish-grey holocrystalline rock of granitoid texture; containing orthoclase (pink), elæolite (dull white), sodalite (bluish white), and ægirine (black).

Microscopic characters.—The bulk of the rock is made up of alkali-felspars (orthoclase and perthite), and elæolite, to which the coloured minerals are subordinate.

The elæolite shows definite crystal outlines and is idiomorphic to the felspar; it has been almost completely altered into dense scaly aggregates of zeolitic material (spreustein).

Most of the felspar is in the form of perthite; it shows evidence of having been considerably crushed and fractured, the cracks in many cases being filled with secondary albite showing twin-lamellæ.

Sodalite occurs in some abundance, in irregular patches or veins.

The coloured minerals, which have crystallized after the felspar, consist of deep-green ægirine and brown acmite.

Accessory minerals are ilmenite altering to leucoxene; numerous prisms of apatite; and occasional crystals of zircon.

A 127. Augite-syenite. Ollachea. (Pl. II, fig. 6.)

A holocrystalline granitoid rock of medium grain, having a mottled black-and-white appearance, owing to the segregation of the coloured minerals into patches.

Microscopic characters.—The association of minerals is that commonly met with in syenites of the laurvikite type and the alkali-gabbros.

The felspars and coloured minerals are present in about equal proportions,

the former consisting chiefly of orthoclase, slightly turbid through decomposition; albite and oligoclase are also present, and perthitic intergrowths are not uncommon.

Elæolite occurs as an accessory, but it has been largely decomposed.

The coloured minerals consist chiefly of a violet-brown titaniferous augite, in the form of large plates intergrown with a deep-brown biotite and containing abundant needles and prisms of apatite.

Magnetite and pyrites are present in about equal proportions; they are frequently intergrown one with the other and surrounded by biotite. A considerable amount of fresh olivine is also met with.

A 124. Mica-syenite. Urahuasi.

A dark-grey holocrystalline rock of medium grain, consisting chiefly of biotite and felspar, the former in excess of the latter.

Microscopic characters.—The felspars, which are subordinate to the ferromagnesian minerals, consist chiefly of plagioclase (oligoclase-andesine), but a considerable amount of orthoclase is also present.

A reddish-brown biotite is abundant, and this is commonly intergrown with yellowish-brown hornblende, the latter usually showing idiomorphic outlines.

A small amount of colourless to pale-green augite is also present.

Accessories include abundant apatite; a little sphene; brilliantly-polarizing prisms of zircon; magnetite; pyrites; and a green spinellid.

A 125. Andalusite-mica-schist. Casahuiri. (Pl. II, fig. 5.)

A finely-banded biotite-schist, containing numerous large crystals of a rose-pink andalusite.

Microscopic characters.—The parallelism of the constituent minerals is not well marked, and the structure as seen under the microscope approaches the granulitic.

The bulk of the rock consists of a fine quartz-mosaic, through which are scattered abundant flakes of biotite and some muscovite.

Andalusite occurs in the form of large well-defined crystals of a faint pink colour, containing few inclusions.

IV. General Summary and Conclusions.

The foregoing paper gives an account of the geological structure of the Andes of Southern Peru, as illustrated by a horizontal section drawn from the port of Mollendo to the Inambari River; and a comparison with a parallel section by the present writer across the Cordilleras of Northern Chile and Bolivia will serve to show that the main structural features there described still find expression in the district under discussion.

Several points of difference, however, will be noticed; gaps in the sequence have been filled in, whereas new gaps appear; vast areas of desert here conceal the continuation of many rocks that are exposed farther south, while in other cases where the exposures are more connected, the beds are frequently observed to undergo a change in character, and additional light is thus thrown on the distribution of land and sea in former geological times.

The rugged foreshore at Mollendo differs markedly in appearance from the stratified cliffs of Northern Chile. The deflexion of the coast-line towards the north-west has here brought to light a zone of ancient granite and gneiss, comparable with the rocks forming the coastal Cordillera of the south. These rocks are shown to be of typical 'alkaline' facies, and it is suggested that their origin dates from a very early period antecedent to the uprise of the

main Cordilleras, which was accompanied by the intrusion of rocks of 'calcic' type.

The continuation of the Jurassic zone of the Morro de Arica and the Llutah and Palca Valleys, lies hidden beneath the desert sands of the Pampa de Clemesi and the Pampa de Islay, an occasional outcrop of barren quartzite on the foot-hills of Cachendo and in the neighbourhood of Ramal being provisionally regarded as the remnants of a formerly extensive Mesozoic cover. Jurassic strata, which proved to be of Bajocian age, were discovered, however, much farther inland at Lagunillas, and are probably also represented by the quartzites of the Sumbay district.

The granitic rocks which form the batholitic core of the Jamiraya district in Northern Chile, were found to be continued in the Palca and Moquegua Valleys, and once more reappear to form the Cachendo foot-hills and the Cerros de la Caldera near Arequipa. The plutonic complex here comprises at least three phases of deep-seated intrusion, represented by the granodiorite of Cachendo and Quishuarani, the augite-diorite of Huaico, and the adamellites of Huagri and Tiabaya.

An interesting example is described of the progressive dynamic metamorphism of a coarse-grained plutonic rock into a fine-grained gneiss. A characteristic feature of the district is the almost complete absence of tourmaline-bearing veins, which are so abundantly associated with the granodiorites of the south.

The line of giant volcanic peaks, which forms the outstanding feature of the Western Cordillera of Northern Chile, is continued into Peru, where Mount Pichu-Pichu, El Misti, and Chachani are seen as an imposing panorama from Arequipa. Many of the augite- and hornblende-andesites found in the neighbourhood of the cones, are of very similar character to those described from Mount Taapaca and Tacora. The volcanic outbursts, however, have chiefly given rise to rocks of a pyroclastic nature, and a wide stretch of country, comparable with that of the Mauri-River district of Bolivia, lies buried beneath a thick mantle of pumiceous tuff.

The red Cretaceous marls of the Coro Coro district, with their deposits of rock-salt and gypsum, are here represented by grey cherty limestones, evidently laid down in more open waters. These limestones are almost devoid of fossils; they are in places much dolomitized, and pass laterally into marls, when they have the appearance of reef-knolls. The transgressive character of the beds is very clearly displayed. At Lagunillas they rest horizontally, with a thick basal conglomerate, on strongly-folded Jurassic rocks, while farther east they overlie with marked unconformity the Devonian beds of Taya Taya.

The post-Cretaceous line of dioritic intrusion, formerly described as running through Coro Coro and Comanche in Bolivia, once more appears along the line of section at Maravillas; the mineralogical character of the rock is almost identical in the two areas, although in the present case it appears to have been somewhat

modified by assimilation of silica during its passage through the Devonian quartzites.

The Devonian series, which crops out in the neighbourhood of Coniri in the south, and is continued beneath the Eastern Altaplanicie of the Viacha district to form the flanks of the Eastern Cordillera, is again exposed here between Maravillas and Las Huertas. The beds are highly fossiliferous, the fauna (of Middle Devonian age) being equivalent to that of the *Conularia* Shales of Steinmann, which have been correlated with the Lower Hamilton Shales of North America.

In the district west of Puno the remnants of a once-extensive sheet of basaltic lava, which appears to have been extruded in the form of a fissure-eruption, are found capping a series of buttes in the neighbourhood of Vilque.

The former extension of Lake Titicaca to the north is further shown by the wide alluvial tracts of the Juliaca area.

The Permo-Carboniferous fauna of Bolivia has not been discovered in the district now described; but rocks of similar lithological character, and probably of the same age, are met with on the shores of the lake near Puno, and again, east of Tirapata, where they overlie Devonian beds.

Fossiliferous beds of Lower Carboniferous age, representing the highest part of the Avonian sequence, occur near Macusani, where they lie unconformably on a much-faulted and folded series of older Palæozoic rocks.

The granitic core of the Bolivian Cordillera does not appear to extend into Peru, or at least is unrepresented along the line of section; an interesting series of alkaline igneous rocks, however, many of them nepheline-bearing, is met with in the Carabaya district near Ollachea. These, locally, show signs of intense dynamic crushing, and are associated with andalusite-mica-schists, which have the appearance of being highly-altered Palæozoic sediments.

The Palæozoic shales of the Caupolican district in Bolivia, described by Dr. J. W. Evans, are again met with in the Inambari district of Peru, and in the valley of the Chaquimayo River yield well-preserved graptolites of Llanvirn age.

An account having been given of the characters and distribution of the rocks which build up the Cordilleras of Southern Peru, it remains to apply the evidence thus accumulated towards elucidating the history of the folded chains.

Ancient igneous rocks, probably of Archæan age, fringe the coast at Mollendo; but, just as is the case in Bolivia, Palæozoic sediments older than the Devonian are confined to the eastern flanks of the Andes drained by the head-waters of the Amazon. After having been penetrated by plutonic intrusions, these rocks underwent a period of orogenic movement, and were subjected to intense dynamic metamorphism.

It is suggested that this folding took place prior to Carboniferous

times, during the period represented by a gap in the succession between Lower Devonian and Upper Avonian deposits. A resistant horst appears thus to have been formed at a comparatively-early date, bounding the Cordillera on the east, and this seems to have been largely instrumental in confining the area of uplift to a narrow strip of country along the Pacific coast.

In Lower Devonian times the sea covered a large tract of the country now forming the Bolivian Altaplanicie and the district north and west of Lake Titicaca, fossiliferous deposits of this age having been determined as far west as Taya Taya.

During Upper Devonian and Lower Carboniferous times the country appears to have been elevated above sea-level, but towards the close of the Avonian period a further great transgression took place, and marine deposits of Upper Carboniferous and Permo-Carboniferous age were laid down over wide areas in the inter-Andean region of Lake Titicaca. In some places they appear to have extended still farther eastwards, and in the Viscachani Valley are seen to lie unconformably on the older Palæozoic rocks.

Indication of the existence of a land-area on the west is afforded by the presence of beds containing Coal-Measure plants on the peninsula of Paracas, south of the port of Pisco.

Marine Triassic beds are unknown in this area, and the complete absence of deposits of later date than Permo-Carboniferous from the Eastern Cordillera suggests that its elevation into a land-area took place about this period.

Further direct historical evidence, however, is wanting until Jurassic times. Rocks of this age form the foundation on which are situated the volcanic cones of the Western Cordillera; but they are largely concealed beneath a later covering of lava and tuff. The Upper Jurassic zone of Northern Chile, extensively developed in the Arica area, has been almost entirely stripped by denudation from the underlying batholitic core, but its continuation has been proved at more than one locality, and farther inland fossiliferous beds of Middle Jurassic age are met with at Lagunillas. On the upturned and steeply-dipping edges of the latter rest horizontal transgressive Cretaceous deposits, giving clear proof of post-Jurassic uplift.

From evidence obtained farther south, we know that volcanic activity had already broken out in Jurassic times, and further light is thrown on the nature of the igneous rocks of the period, now buried beneath later deposits, by the occurrence of numerous derived pebbles in the basement conglomerate of the Cretaceous Series. Among these are found rocks of plutonic origin which bear a striking resemblance to those forming the core of the Western Cordillera.

It would appear, then, that the batholitic invasion took place, in part at least, prior to or during the post-Jurassic uplift, and, moreover, that this was sufficiently great to bring the deep-seated core into the zone of active erosion before Cretaceous times.

There is, in fact, no direct evidence that Cretaceous rocks were

ever laid down over the coastal region in this area, and the deposits of this age in the inter-Andean region may have been formed in a bay or land-locked arm of the northern sea. Thus we may seek to explain the gradual transition from the widespread fossiliferous limestones of the north into the red sandstones and gypsiferous marls of the south. The Cretaceous rocks shared in the folding which took place during Tertiary times, and, as is also the case in Bolivia, have been penetrated by later intrusions of diorite. The fact that these marine deposits are now found at altitudes over 13,000 feet above sea-level gives some idea of the magnitude of the Tertiary uplift.

Volcanic activity continued with renewed vigour, and the giant cones of the Western Cordillera were gradually built up to heights even greater than they possess at the present day. Some of them, although dormant or extinct, still retain, like El Misti, a well-preserved crater; others, like Chachani, have been dissected by long-continued erosion, and retain little of their original form.

With regard to the date and extent of recent uplift there is conflicting evidence. It has already been argued that the presence of an extinct mammalian fauna at 13,000 feet in the Desaguadero district of Bolivia can only be explained by the assumption of a considerable post-Pleistocene elevation, and it appears likely that the gently-sloping rock-platform fringing the coast of Southern Peru was formed at the same time. A still more recent elevation is indicated by the raised beach at Mollendo; but there appears to be no conclusive proof that any extensive movement has occurred during the period of human history.

It thus becomes clear that the area now occupied by the folded chains of the Andes has been subjected to repeated oscillations: periods of uplift, marked by folding and erosion, having alternated with periods of submergence, marked by the deposition of transgressive formations.

The general history of the Cordillera may be tabulated as follows:—

Deposition of Older Palæozoic rocks, up to and including the Lower-Middle Devonian.

Upper Devonian uplift.

Permo-Carboniferous transgression.

Permo-Triassic uplift.

Jurassic transgression.

Post-Jurassic uplift; accompanied by batholitic invasion.

Cretaceous transgression.

Mid-Tertiary uplift (amounting to at least 14,000 feet), accompanied by a great outburst of volcanic activity.

Post-Pleistocene uplift (probably amounting to about 1500 feet).

It may be as well to postpone any detailed discussion on the nature of the folding, until the description of the structure of the more northern districts of Peru has been completed. A brief

statement of the observations made in the area now described may, however, not be out of place here.

A journey through the Pre-Alps of Chablais, made some years ago, under the leadership of Prof. Lugeon, enabled me to draw a comparison between the structure of a mountain-chain of Alpine type and that presented by the Cordilleras of the Andes. After becoming acquainted with the latter, I could not fail to be impressed by the complete dissimilarity of the two types of structure.

Preconceived notions of vast sheets or recumbent folds, transported over wide areas and separated from their roots to expose an underlying 'yoke,' were at once swept away. Throughout the Peruvian Cordilleras, inverted folds are the exception rather than the rule, and great zones of overthrusting appear to be entirely wanting. Any directional movement of the folding, moreover, is hard to determine, and the relationship between that part of Gondwanaland represented by the Brazilian platform and the folded chains of the Andes is, in the light of recorded facts, still obscure.

(Suess, in a summary of the structure of South America, makes the two following contradictory statements: 'In South America the Brazilian mass occupies the place of the backland within the arc, and the foreland lies beneath the ocean'; and later 'In about the latitude of the Bay of Arica the western promontory of Brazilia was overwhelmed by the folding movement directed towards the east.')

Relying on my own observations, I am led to believe that the folded chains of the Andes are the result of intermittent compression of a series of transgressive deposits, laid down in a geosyncline, between two ancient resistant masses, represented on the east by the metamorphic and plutonic rocks of the Amazon region, and on the west by the crystalline rocks of the coastal Cordillera. The trend-lines of the system, according to this theory, were determined at a comparatively-early date, and the areas covered by later transgressions were therefore limited by the continued rise of the chains on the east.

In the Alpine type of folding vertical uplift has been overshadowed by movement in a horizontal direction, whereas in the Andean Cordilleras the reverse is the case, and the terms 'backland' and 'foreland' as applied to the direction of movement have no longer the same significance.

Attention may once more be drawn to the fact that in the two marginal areas the igneous rocks are of 'alkaline' facies, whereas the later plutonic and extrusive rocks of the chains themselves are of 'calcic' type; and, if we assume that relief from increasing compression was eventually afforded by deep-seated dislocation, possibly in the form of submarginal thrust-planes, an explanation is offered for the great batholitic invasion of the chain by a granodioritic magma in post-Jurassic times.

V. Bibliography.

This list is a continuation of and supplementary to one published in a former paper of this series (No. 35 *infra*), to which reference may be made for further works dealing with the Geology of Peru and Bolivia.

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EXPLANATION OF PLATES I–VI.

Plate I.

Fig. 1. *Conularia africana* Sharpe, Lower Devonian; Taya Taya (Peru). Natural size. (See p. 37.)

2. *Conularia baini* Ulrich, Lower Devonian; Taya Taya (Peru). Natural size. (See p. 37.)

3. *Conularia quichua* Ulrich, Lower Devonian; Taya Taya (Peru). Natural size. (See p. 37.)

4 *a*. *Cyathaxonia* sp., Carboniferous Limestone; Viscachani (Peru). Transverse section of adult stage, showing solid central axis, and regular disposition of septa. Natural size. (See p. 46.)

4 *b*. Transverse section of adolescent stage, showing breaking-up of septal ring (cf. *Carcinophyllum simplex* Garwood). Natural size. (See p. 46.)

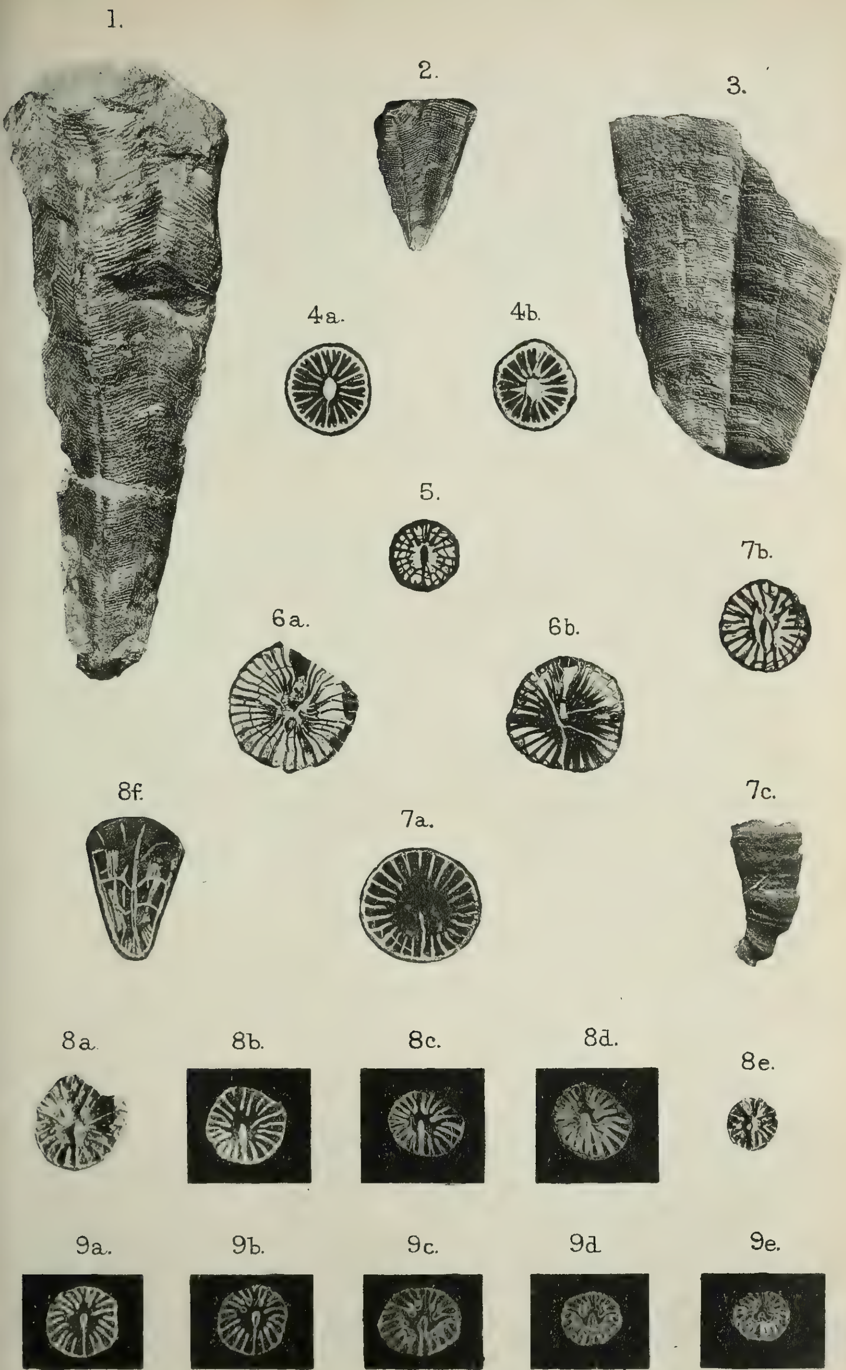
5. *Zaphrentis* aff. *eruca* (M'Coy), Carboniferous Limestone; Viscachani (Peru). Transverse section, showing Lophophylloid type of columella formed by the lateral thickening of the counter-septum, and the regularity of the tabular intersections. Natural size. (See p. 45.)

6 *a*. *Zaphrentis* aff. *enniskilleni* Edwards & Haime, Carboniferous Limestone; Viscachani (Peru). Transverse section, adult stage, near the floor of the calyx, showing the expansion of the cardinal fossula, and thin major septa with curvature convex to the fossula. Natural size. (See p. 46.)

6 *b*. Transverse section, adolescent stage, showing expansion of the narrow fossula near the wall, and thickened septa. Natural size. (See p. 46.)

7 *a*. Lophophylloid *Caninia*, Carboniferous Limestone; Viscachani (Peru). Transverse section, adult stage, near the floor of the calyx, showing the Amplexoid character of the septa, and the extension of the counter-septum. Natural size. (See p. 45.)

7 *b*. Transverse section of another specimen, adolescent stage. Natural size.



J.A.D., Photo.

Bemrose, Collo, Derby

FOSSILS FROM THE ANDES (MOLLENDO-INAMBARI SECTION).

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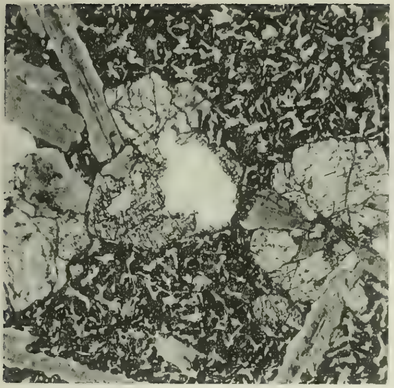

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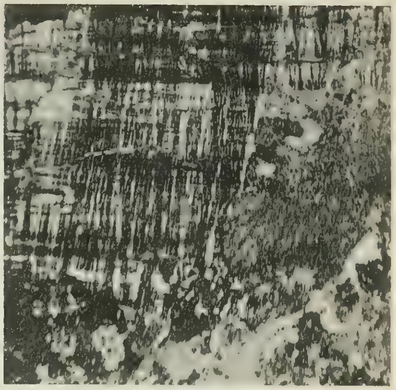

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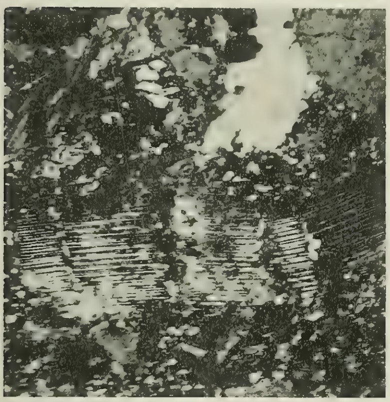

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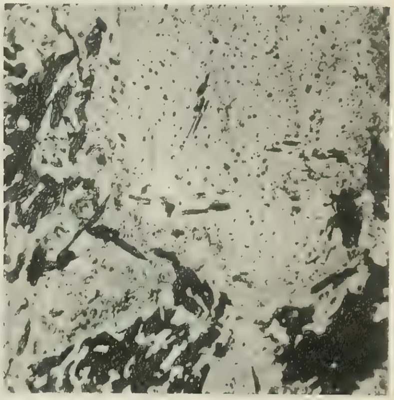

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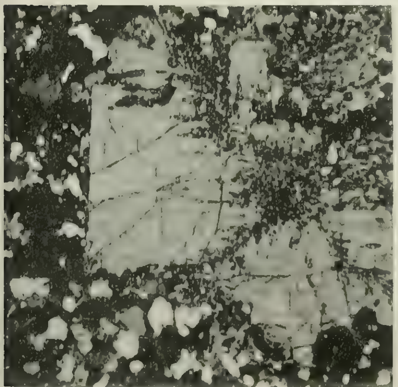

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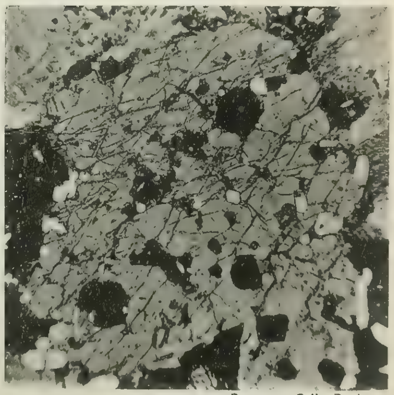


J. A. D., Photomicro.

Bemrose, Collo., Derby.

IGNEOUS ROCKS FROM THE ANDES (MOLLENDO-INAMBARI SECTION).

Quart. Journ. Geol. Soc. Vol LXXVI, Pl. III.

J. A. D. photo.

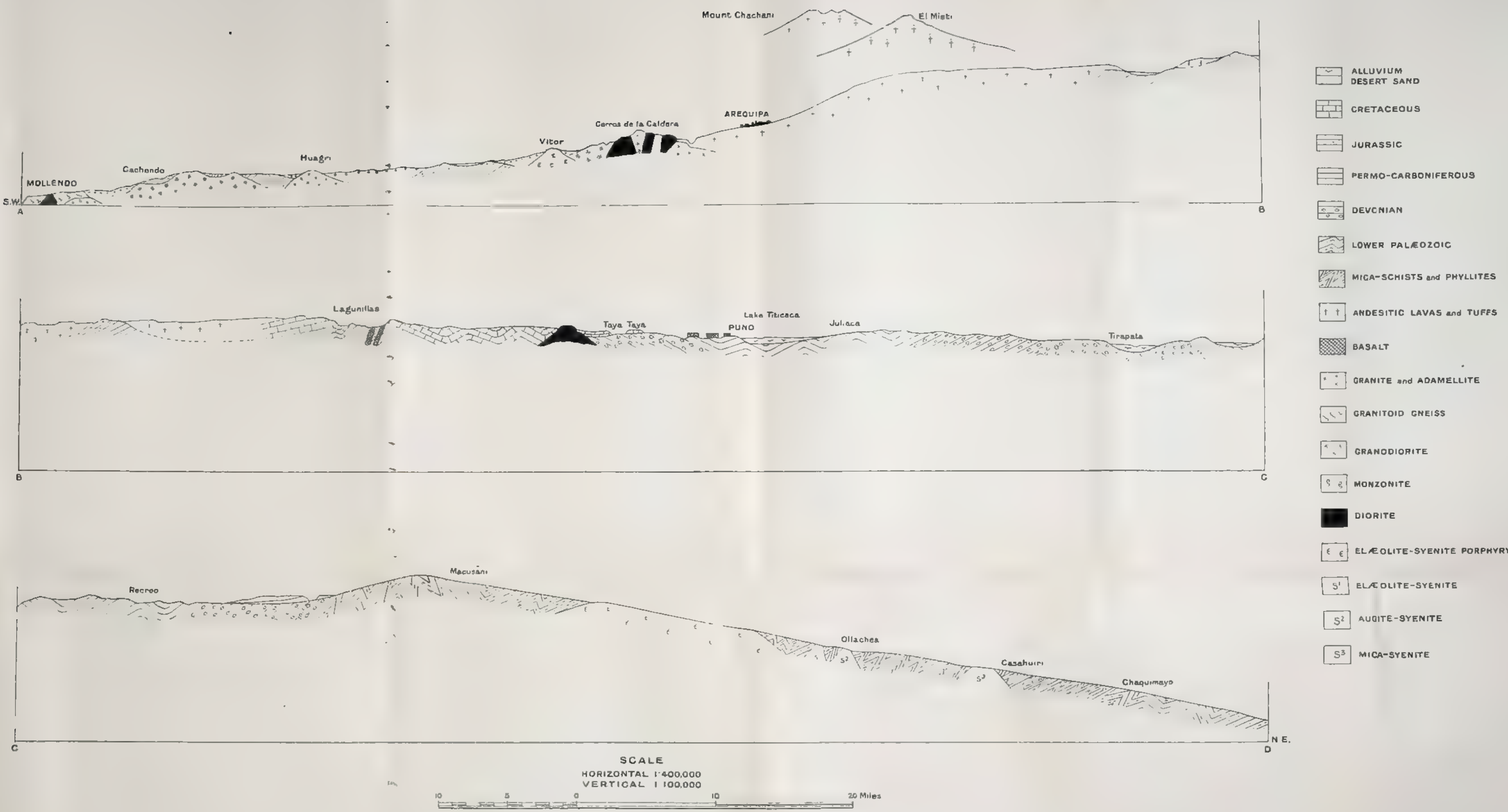
RAISED BEACH AT MOLLENDO.

CRATER OF EL MISTI.

H. C. photo.

DEVONIAN BEDS OF TAYA TAYA.

J. A. D. photo.



GEOLOGICAL SECTION THROUGH THE ANDES FROM MOLLENDO TO THE INAMBARI RIVER.

Fig. 7 *c*. Profile view of a typical corallum, showing the irregular nature of growth. Natural size. (See p. 45.)

8 *a*. Lophophylloid *Zaphrentis*, Carboniferous Limestone; Viscachani (Peru). View of calyx. Natural size. (See p. 44.)

Figs. 8 *b*–8 *d*. Serial transverse sections showing septal development and Lophophylloid columella. Natural size.

Fig. 8 *e*. Weathered specimen of young individual, showing extension of the counter-septum through the central axis. Natural size.

8 *f*. Vertical section of another specimen through the centre of the corallum, at right angles to the counter-septum; showing the cut end of the latter as an axial rod penetrating the region of the cardinal fossula, as indicated by the depression of the tabulæ. Natural size.

Figs. 9 *a*–9 *e*. Lophophylloid *Zaphrentis*, Carboniferous Limestone; Viscachani (Peru). Serial transverse sections of a specimen, showing septal development and cardinal and alar fossulæ. Natural size.

[Figs. 7 *a*, 8 *b*–8 *d*, 8 *f*, 9 *a*–9 *e*, are of ground and polished specimens.]

Plate II.

Fig. 1. A 97. Dolerite, Mollendo: showing subophitic augite partly enclosing lath-shaped crystals of plagioclase (andesine), the cloudy appearance of the latter being due to the presence of minute schiller-inclusions. (In ordinary light, × 36 diameters.) See p. 11.

2. A 91. Granite, Mejia: showing a large crystal of microcline. (Between crossed nicols, × 24 diameters.) See p. 10.

3. A 79. Granodiorite, Quishuarani: showing the first stage in dynamic metamorphism, with distortion and fracture of plagioclase. (Between crossed nicols, × 24 diameters.) See p. 22.

4. A 76*a*. Xenolith in granodiorite, kil. 129: showing the result of the recrystallization of the component minerals. Andesine (clear), with abundant inclusions of magnetite and hornblende. Bluish-green hornblende (tinted); and biotite (black). (In ordinary light, × 24 diameters.) See p. 21.

5. A 125. Andalusite-mica-schist, Ollachea: showing a large crystal of andalusite. (Between crossed nicols, × 24 diameters.) See p. 52.

6. A 127. Augite-syenite (laurvikite), Ollachea: showing titaniferous augite; olivine; apatite; orthoclase; and magnetite (black). (In ordinary light, × 24 diameters.) See p. 51.

Plate III.

Raised beach at Mollendo.

Plate IV.

View of the crater of El Misti.

Plate V.

Devonian beds of Taya Taya.

Plate VI.

Geological section through the Andes, from Mollendo to the Inambari River. Scales: horizontal, 1 : 400,000; vertical, 1 : 100,000.

Discussion.

Dr. J. W. Evans congratulated the Author on the excellent work that he had accomplished. The ground that the speaker had the opportunity of examining in the Eastern Andes lay between the sections described by the Author in his two communications to the Society. It differed, in some respects, geologically from the region that had been dealt with on the present occasion. The Carboniferous formation occurred in the first and third synclines (counting from the west) in the Palæozoic rocks, but not in the second. Farther east the latter had been thrown into isoclinal folds, which included beds of Tremadoc and Llandeilo age, and possibly pre-Cambrian strata, but no crystalline schists; nor were there (with perhaps one unimportant exception) any soda-rocks. The low ground between the Palæozoic ridges was occupied by red rocks believed to be of Cretaceous age.

Prof. G. S. Boulger, having some years ago traversed the line of the Author's section throughout, thanked him for his admirable description of the geological structure of the country. He enquired as to the source of the lateritic deposits in the river-valleys at the eastern foot of the Andes.

Mr. W. Campbell Smith asked whether the Author had any evidence, other than the presence of the quartz-grains, to support his suggestion that the dioritic intrusion, shown in the section west of Taya Taya, had absorbed the Jurassic quartzite through which it was intruded, and that the quartz-grains were the relics thereof. The suggestion involved the acceptance of the 'stoping' and almost complete solution of a quartzite by a dioritic intrusion. This seemed an important point, on which further evidence was desirable.

Prof. W. J. Sollas also spoke.

The Author, in reply to Dr. Evans, said that he was himself convinced that the mica-schists of the San Gaban valley were largely the result of dynamic metamorphism, for the associated igneous rocks furnished clear proof of intense crushing. He did not claim, however, that this metamorphic zone was of wide lateral extent, and he had not met with it in the district east of La Paz. He was not surprised, therefore, to hear from Dr. Evans that it did not occur in the Caupolican area. This fact appeared to the speaker to lend strength to his suggestion that these ancient rocks had been instrumental in checking the advance of the folds into the Brazilian platform: for in the south, where they were absent, Dr. Evans had described subsidiary forefolds, and the Carboniferous transgression was of wider extent.

He agreed with Prof. Boulger that much of the soil in the forested region was due to lateritization; he had found extensive deposits of laterite in the Chanchomayo district, and regarded it as the normal product of weathering in these latitudes.

The Author found it difficult to account for the pre-Inca civilization of the High Andes, except on the assumption of a recent elevation; a corresponding depression of about 1500 feet would render the country round Tiahuanacu capable of cultivation. He referred once more to the pre-Spanish burial-tumuli, just above high-water mark near Arica, as precluding the possibility of any elevation of the coastal region since historic times. This, in his opinion, did not necessarily apply to the high plateau.

In conclusion, he expressed his gratitude to the late Mr. W. E. Balston, who enabled him to visit South America, and shared in Prof. Sollas's regret that Mr. Balston had not lived to see the result of the expedition which bore his name.

2. Jurassic Chronology: I—Lias: Supplement I, West England Strata. By S. S. Buckman, F.G.S. (Read January 7th, 1920.)

Contents.

I. Introduction.

My last communication [1] left many matters unproved, with indications where further research was required. Three points especially were—

(1) The presumed faunal repetition of *Uptonia*;

(2) The Gloucestershire sequence between *Phricodoceras* and *bronni* (Wessexian 1 to 7), of which it was unknown whether the failure of records was due to lack of strata or, as I was rather disposed to think, to lack of exposure;

(3) The sequence in early Raasayan—pre-*subplanicosta*.

Information concerning these three points may be gleaned from two interesting papers published by Mr. L. Richardson [2] while my communication was in the press. With his information it is now proposed to deal by a method of faunal plotting, which will afford good opportunity of testing faunal dissimilarity by faunal analysis, and seeing how the results accord with those of my former paper. They appear to be specially instructive and to show such considerable possibilities for the application of faunal plotting to wider fields that they seem to deserve record. Hence this communication is offered to the Society.

The first of Mr. Richardson's papers records the faunas found in a number of cuttings exposing strata which range from Hwiccian 5,[3] of my paper, to Deiran 4[4]; while the second, describing an

[1] II, 8, see Bibliography, p. 101.
[2] XVIII, 1.
[3] II, 8, p. 264.
[4] II, 8, p. 269.

excavation for a gasometer, has in my opinion dealt with a fauna in part from a still lower horizon, about Mercian 7[1]; though Mr. Richardson locates it all as *oxynotum*,[2] say early Deiran.

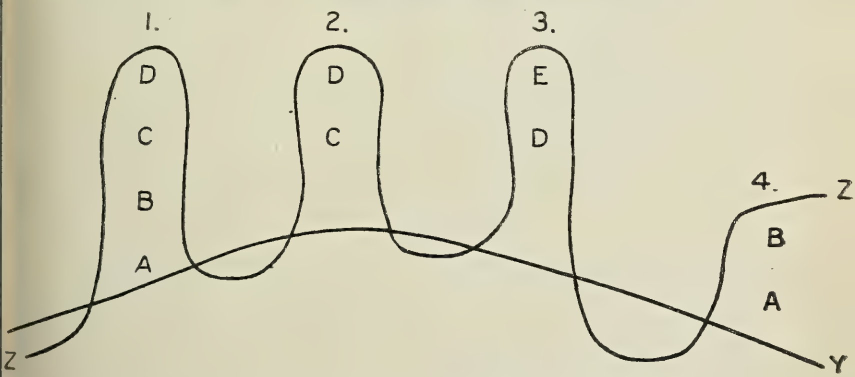
The specimens were not collected *in situ*, except in one instance —an almost impossible task with modern methods of railway-construction,—and hence it might be thought that the evidence would not be good. But the range of the strata which Mr. Richardson has divided into seven or at the most eight hemeræ cover, according to my more detailed subdivisions, thirty-two hemeræ, and should afford a good test as to whether this more detailed method of dating makes for greater precision in recording knowledge of local deposits.

II. Faunal Analyses.

(*a*) Methods of Work.

The problem presents itself in this way—given sections along a line of country disclosing dissimilar faunas—in this case Ammonites and certain Brachiopods are the subject of the enquiry,—find the sequence of the deposits from the recorded faunas. It is obvious that, if the various sections be placed in their geographical order—

Fig. 1.—*Supposititious faunal analysis.*



in the present case easy, as it is approximately a straight line of country—, and if the species be correctly placed in sequence, a series of regular curves without gaps must result from the plotting of the faunal analyses according as the sections are through higher and lower strata. To illustrate this, suppose that there are taken four localities with five species represented by the letters A–E. Then the above supposititious diagram may result (fig. 1)—the curve Y represents the line of the railway, the other (Z) the line of hill and vale; and the places numbered are the cuttings; in between are hollows bridged by embankments or otherwise.

[1] II, 8, p. 271. [2] XVIII, 1, p. 155.

It is obvious from this diagram that only the species A and B can be, not necessarily of the same date, but lying side by side in the same deposit, by no means an identical proposition (see p. 85). If C and D were in like condition, then section 3 should disclose C.

If the line of railway be approximately level, then with the same records a syncline of strata will be exposed. If the two middle records changed places respectively with those outside, then an anticline will be shown.

If, however, the record presents itself as in fig. 2, then there are

Fig. 2.—*Supposititious faunal analysis.*

1.	2.	3.	4.
		E	
D	D		
	C	C	
			B
A			A

lacunæ in 1 & 3, and it is necessary to consider the various factors which may produce such gaps. These are :—

I. Stratal failure due to penecontemporaneous erosion, or to lack of deposit—depositional failure.

II. Faunal failure—due either to I, or to

III. Dispersal failure—limited horizontal range of fauna.

IV. Exposure failure—failure to uncover a portion of deposit at a certain place.

V. Collection failure—incomplete collection of available specimens.

VI. Arrangement failure—the order of species is plotted incorrectly.

VII. Nomenclature failure—especially lumping.

There are also other phenomena to be considered—to account for faunal lacunæ, but they could not well be urged with regard to contiguous exposures. They will be considered later (see p. 89).

As regards I, stratal failure, it is now known from work in the Jurassic rocks for many years, sufficiently illustrated in the Society's Journal, that non-sequences due to penecontemporaneous erosion are almost the rule and true sequences the exception; that the non-sequences have sometimes a horizontal range of several miles, but that the effects of the erosion can be detected in a range of a few yards—intermediate fauna and strata at one end of a quarry or cutting having been wholly or partly removed from the other. Here then is one reason for gaps in the faunal sequence: such gaps should show themselves not as isolated lacunæ, but as following regular curves of thinning and thickening—lenticular lacunæ. Stratal failure due to depositional failure would be a doubtful point in contiguous exposures, but would have to be considered in comparison of separated areas.

So far as II, faunal failure, is concerned, there are two causes for this phenomenon,—one that of stratal failure (I), and the other that of dispersal failure (III). But it is obviously most unsafe to postulate the latter, until certainty has been arrived at that the former is not the cause. For, as the former (stratal failure) means failure of the accompanying fauna in most cases—though sometimes the fauna is redeposited in a later bed—, the former is a sufficient cause of the latter. As the former is a very common phenomenon, it is obviously safer to assume it as the cause of faunal failure rather than to lay it to dispersal failure—a phenomenon about which little is accurately known. Yet, judging by recent writings, the tendency is to jump at the latter conclusion as the cause of faunal failure. On this point a few words will be said presently.

Exposure failure (IV).—This would not occur in railway-cuttings, but might occur in a series of quarries. It is obvious in regard to some of the subsidiary excavations connected with the railway from which fossils are recorded by Mr. Richardson. As these records would hinder rather than help the result, I have disregarded them in the present case.

Collection failure (V) and arrangement failure (VI).—The former might result from many causes—lack of time, incomplete searching, inaccessibility of places, rarity of species or specimens, inability to bring away large specimens: it is needless to consider these and other possible factors in detail, as they would be obvious to geologists; it may be judged that some of them do not apply in the present case. But the point to be made is that collection failure, in the case of several exposures in a limited area, should, if the species have been arranged in correct order, disclose itself by abrupt local lacunæ. On the other hand, if the species have been arranged in incorrect order (arrangement failure) there would obviously be many such local lacunæ. To attempt to account for these as collection failure would be a reflection on the collector. A few local lacunæ may be accounted for mainly as collection failure; many local lacunæ as, more likely, arrangement failure.

In regard to VII, nomenclature failure, that can present itself in many ways and in varying degree. Faulty nomenclature would produce arrangement failure; lumping nomenclature—attribution of the same name to different species occupying different horizons—would produce local lacunæ.

With many of the unillustrated and uncritical records which have appeared in geological literature it would be almost impossible to attempt anything—at least without very liberal interpretation, which even then might be insufficient. But Mr. Richardson's nomenclature is quite satisfactory: it is as good as could be produced without a prolonged technical investigation, which no one has yet carried out with these species. Translation in a few cases with 'cf.', 'aff.', and so forth is ventured from experience in collecting from similar spoil-heaps in other parts of Gloucestershire many

years ago: I am speaking now more especially of the *subplanicosta* and associated horizons of the Raasayan; and a few notes on such interpretation will be given. But, before proceeding farther, it seems desirable to say a few words about faunal failure, ascribed to dispersal failure and not to the very common phenomenon of stratal failure.

First for notice are Dr. W. D. Lang's remarks on fishes, contributed to the discussion of my former paper[1]:—

'Ammonites may have had very restricted horizontal ranges.... Many marine fishes are strictly limited in their horizontal distribution.'

The analogy does not hold in any way. All the knowledge possessed about the distribution of fishes would belong to, say, 200 years; the strata of a hemera must be the accumulation of deposits through some thousands of years. It cannot be said that in a freely open sea the present geographical ranges of species of fishes have been, are, or will be permanent during all the time necessary to deposit the strata of a hemera. If in open areas the geographical ranges are only temporary, then it can be argued that such temporary phenomena would, when packed away in the strata of a hemera, make no showing at all. Deposition must have been so slow in relation to dispersal that a few hundreds of years' difference in arrival at various places would be marked by no appreciable depositional criteria: geologically, it would be synchronism.

Further, the analogy does not hold, because the method of work with the fossils is not concerned with species of merely local distribution—a species which ranges from Gloucestershire to Würtemberg, or from Somerset to the Rhone Basin, is not a species of local distribution. Its failure in contiguous or intermediate areas is what has to be explained. In passing from Somerset to the Rhone, or *vice versa*, a species must have left dead on the way to mark its trail. Why are they not found in Dorset? Land-barriers come into play in some cases, as will be shown presently; but they must not be called in for cases like this, where a little later and a little earlier certain ammonite species are found ranging from the Rhone Basin to Yorkshire and even to the Hebrides, but failing in some intermediate areas. And the failure of the ammonites is not the sole evidence; often there is direct proof of the failure of their strata: thus a bed *c* with its own fauna is found resting directly on bed *a*, leaving no room for bed *b* which is found in neighbouring areas on bed *a*.

Next may be noticed a remark by Mr. L. F. Spath in a footnote to his paper 'Notes on Ammonites'[2]:

'Compared with the almost universal distribution of the genus *Macrocephalites*, this restriction of *Clydoniceras* [in the southern part only of the Cornbrash outcrop in England] is interesting, and shows that, like many modern marine organisms, certain Ammonite genera were undoubtedly strictly limited in their horizontal distribution.'

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[1] X, 2, p. 326.

[2] XIX, p. 31.

And he gives the perhaps unfortunate impression that, from this single instance of *Clydoniceras*, he comes to a conclusion which is 'undoubted' about its strictly-limited horizontal distribution; but, at any rate from his having chosen it, one may infer that he regards it as an excellent example. Unfortunately, it is about the worst example that he could have chosen, for he is not dealing with comparable genera, as they are not of the same date,[1] and he seems to have neglected to consider all the factors involved, as I may have occasion to show at another time. Of course, the horizontal distribution of all organisms is limited, more or less; but the point to be proved in citing the failure of *Clydoniceras* north of the Humber is whether it is due to stratal failure or to dispersal failure. As I have remarked above, the analogy with the distribution of modern organisms does not hold. The further question arises, what is meant by the term 'limited horizontal distribution'? Mr. Spath remarks in the same paper (p. 68):

'*Polymorphites* . . . an unstable genus . . . of limited horizontal distribution.'

As *Polymorphites* ranges from Yorkshire in the north to Würtemberg in the south, about as far as the sea at that time allowed it to range in those directions, for north of Yorkshire deposits have been destroyed or lie buried under the sea—this is not limited horizontal range in my meaning. That term I would apply to the range of *Terebratula fimbria* and some other Oolite-Marl brachiopods of the Aalenian of the Cotteswolds—their range limited to a few square miles of Cotteswold Hills, where the strata happen to have been preserved. Their present geographical range may be assumed to be less than their actual range was; because on the south and east there is stratal failure due to considerable penecontemporaneous erosion, and on the north and west the same failure due to post-Eocene or other erosions. But this is what I call 'limited horizontal range,' because in preserved contemporaneous strata of other parts of England these species are lacking. For some reason, these and many other Cotteswold brachiopods of Aalenian-Bajocian times could not migrate even a few miles south and south-westwards to areas where other contemporaneous brachiopods flourished, which were equally unable to pass to the Cotteswoldian grounds: here the intervention of a land-barrier seems to meet the case.[2]

But, while the range of the Cotteswoldian brachiopoda may be said to be limited, that of their contemporaries in the South of England was not—some of them ranged into France and even farther. Faunal analyses and comparison will yield some very

[1] *Clydoniceras* lived before, and *Macrocephalites* lived after, the great change in Eurasian maritime geography—the great submergence which opened up large areas to marine organisms. Further, the experience gained in this chronological investigation (as my last paper shows) should warn us about accepting *Macrocephalites* as indicating only one date—its species may belong to series in sequence like the *Echiocerata* of the Raasayan, or be instances of faunal duplication like *Uptonia* or the armatoids.

[2] II, 1, p. 381.

striking details in this connexion, which, however, must be held over for the present.

Nevertheless, it is surely rash to invoke a land-barrier as a kind of *deus ex machinâ*, especially on little or no evidence. Thus Mr. M. Odling,[1] speaking of the Yorkshire Cornbrash, says

'That it is homologous to the South-country Cornbrash is fairly clear, but it was probably deposited in an area cut off from the main mass by some land-barrier.'

Yet on the next page he gives a diagram of the same Cornbrash zone of *macrocephalus* in Wiltshire and Yorkshire: quite correct, but making a land-barrier seem superfluous.

Farther on in the same paper, Mr. Odling remarks:

'The absence of a particular ammonite need not necessarily mean the non-deposition or contemporaneous erosion of beds of this particular age, but merely that this form was not so rapidly distributed.'[2]

This brings us back to the horizontal range question again. As the repetition of this idea evidently voices current geological teaching—shows that teaching repeating phrases heard for the last forty years—, it seems advisable to refer readers to certain remarks about zone-species in my former paper,[3] and to add that the absence of an ammonite from a locality is only the first observation to make. This leads to the question—to which of the causes mentioned above as making lacunæ may its absence be due? This should lead to further observations; and, if by them one is satisfied that nomenclature failure and certain other causes can be ruled out, then comes the choice between stratal failure and dispersal failure. To settle this, observations on geographical range are required; and, if the range is found to stop short at the area of absence, then dispersal failure may be assumed, though it is not necessarily proved. But, if the range extends well beyond the area of absence, then dispersal failure would be an almost untenable theory; while stratal failure, which has already proved to be an extremely common phenomenon, and seems likely to be proved to be yet much commoner, may reasonably be invoked as a cause of the local absence.

One pursues this method of work so much as a matter of instinct, that the setting forth in detail of a course which appears so obvious seems to require an apology.

The analyses of Mr. Richardson's finds of ammonites and certain brachiopods which are now presented (Table I, facing p. 70) should illustrate these methods of work.

(*b*) Faunal Data.

For the preparation of Table I the only available data are (1) the sequence of ammonites above the *bronni* clays,[4] which is

[1] XII, 1, p. 279. [2] *Ibid.* p. 283. [3] II, 8, p. 278.

[4] Mr. Richardson assigns the *bronni* clays to a much earlier date. 'Hemera: late *raricostati* or early *armati*, probably the latter' (p. 158, Explan. pl. ii, figs. 27 & 28): a position about 12 hemeræ too early, according to the researches of my former paper (II, 8, p. 266).

fairly well-known already; (2) the following sequence given by Mr. Richardson from one locality, Bayliss Hill, near Honeybourne (Worcestershire), which can be epitomized as follows:—

Bed 1.	*Bifericeras subplanicosta*,
	Polymorphites polymorphus,
	Microceras densinodum,
Bed 2.	*Microceras densinodum*,
Bed 3.	*Echioceras raricostatum*.
	Oxynoticeras guibalianum;

(3) the inference to be gathered from Mr. Richardson's remarks about the Toddington cutting, that *Bifericeras tubellum* must be high up in pre-*bronni* beds. This finds a certain amount of support from Yorkshire, where *Ammonites tubellus* is reported as well above the *subplanicosta* beds.[1] With these details for a guide the accompanying table (I) has been constructed—the different exposures (1–16) running practically in a line from south-west to north-east, approximately along the strike, though rising to pass through a tract of higher ground in the neighbourhood of Dixton, as the diagram reveals.

(*c*) Faunal Notes.

The following remarks concerning some of the species are a necessary prelude to any consideration of the facts brought out in the Table.

Oistoceras arcigerens. This is supposed not to be an *Oistoceras*, but a species of *Amblycoceras* as interpreted by Dr. A. E. Trueman,[2] similar to species of the *capricornum* bed of Pilley, Leckhampton (Gloucestershire), Hwiccian 5, and not to indicate *Oistoceras* Beds (Hwiccian 9).

Polymorphites polymorphus. This is an incorrect identification, for which I am possibly responsible; at any rate, it echoes a misidentification which I gave many years ago. It is possibly not a *Polymorphites*; it is certainly not *polymorphus*, which is a lineate form. This species, if there are not more than one involved, is sometimes smooth, sometimes faintly rugose. It has a likeness to *Ammonites electre* Reynès,[3] *A. abnormis* Hauer in Reynès,[4] and to *Psiloceras abnorme* Hauer in Geyer,[5] which is, however, larger and more rugose. It is also curiously similar to the young *Ammonites hartmanni* figured by Dumortier,[6] an identification which seems suspicious because of its entire lack of even a nascent carina, and because it does not come from the same locality as the larger examples.

Microceras densinodum. Here are combined the various forms recorded by Mr. Richardson under *Microceras*. They are

[1] II, 6, p. 70.
[2] XXI, 1, p. 279.
[3] XVII, pl. xxxiv, figs. 12–15.
[4] XVII, pl. xliii, figs. 13 & 14.
[5] VIII, pl. ii, figs. 24 & 25.
[6] VI, pl. xxi, figs. 8 & 9.

presumed to belong to the series allied to *Ægoceras obsoletum* Blake (*non* Simpson). [See *Crucilobiceras crucilobatum* S. Buckman, II, 9, pl. clxxviii, September, 1920. The forms are usually colomorphs of, or aff. this species.]

DEROCERAS ARMATUM. I have ventured to translate the species which are recorded under *Deroceras* as armatoids belonging to a horizon lower than the *subplanicosta* bed. *D. armatum*, so far as is known at present, is a species of a horizon above that; and *D. submuticum* Dumortier is a species of a still higher level—*leckenbyi* (Raasayan 7). One may suggest the addition of 'cf.' to the names of the species found by Mr. Richardson.

I venture to think that the species recorded as *Deroceras armatum* in connexion with *Bifericeras tubellum* at Toddington cutting may be different from that in the pre-*subplanicosta* horizon. And it will be noted that in Table I there is a suspicious gap above *Deroceras* under Bishop's Cleeve. If these two records could be raised to a post-*tubellum* position the diagram would be much improved.

ECHIOCERAS RARICOSTATUM. Here are combined the various records of Echioceratés which presumably require the same addition of 'cf.'

OXYNOTICERAS GUIBALIANUM and sp. I venture to interpret these as belonging to *Gleviceras*.[1]

OXYNOTICERAS FERRUGINEUM. This is presumably to be interpreted as *O. flavum*[2] (Simpson) homœomorph of *Ammonites ferrugineus* Simpson, which belongs to the Domerian (about 6, *lævis*) and genus *Amauroceras*.[3] This may possibly indicate the *simpsoni* horizon.

RHYNCHONELLA [ROSTELLATA (Quenstedt)] is the form which Mr. Richardson has recorded as *Rhynchonella* sp., so abundant at Toddington. He very kindly gave me some specimens several years ago, but I had not then recognized it. I have also found the species among my father's Cheltenham specimens. Some of the Gloucestershire forms are rather larger than those from Würtemberg, but otherwise it conforms with Würtemberg specimens kindly sent by Dr. Rau. It belongs to the same limited group as *Rh. thalia* (genus *Tropiorhynchia* S. Buckman)[4] and is a sort of dwarf development of that species. Its presence links the strata of Gloucestershire and Würtemberg (see p. 72).

Quenstedt figured *Terebratula rostellata* as from Lias δ (Domerian), but that is a mistake corrected by Dr. Rau.[5] The label with his specimen is 'Lias γ unten.'

[1] II, 8, p. 289. [2] II, 4, No. 55, vol. i, 1912.
[3] II, 4, ii—Systematic, p. *vii*, 1913; II, 9, pl. cxlii.
[4] II, 5, p. 1; II, 7, p. 33. [5] XVI, p. 289.

TABLE I.—FAUNAL ANALYSIS.[1]

	1. Chestnut Farm.	2. Hunting Butts.	3. Evesham Road.	4. Bishop's Cleeve.	5. Gotherington.	6. Dixton West.	7. Dixton East.	8. Greet.	9. Isbourne.	10. Hailes.	11. Didbrook.	12. Toddington.	13. Stanton Fields.	14. Broadway.	15. Weston Subedge.	16. Bayliss Hill.
......						×										
......						×		×								
......					×		×	×								
e, ...											×					
......					×	×	×	×			×					
......						×				×						
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......	×	×	×	×								×	×	×		
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......													×	×		
......													×	×		
......													×			
......													×			

d by Mr. L. Richardson. For remarks on them, see Faunal Notes, p. 69.

TABLE I.—FAUNAL ANALYSIS.[1]

	1. Chestnut Farm.	2. Hunting Butts.	3. Evesham Road.	4. Bishop's Cleeve.	5. Gotherington.	6. Dixton West.	7. Dixton East.	8. Greet.	9. Isbourne.	10. Hailes.	11. Didbrook.	12. Toddington.	13. Stanton Fields.	14. Broadway.	15. Weston Subedge.	16. Bayliss Hill.
23. *Oistoceras arcigerens*						×										
22. *Lytoceras lineatum*						×		×								
21. *Androgynoceras capricornu*					×		×	×								
20. *Acanthopleuroceras solare, quadratum*											×					
19. *Liparoceras cheltense*					×	×	×	×			×					
18. *Acanthopleuroceras* spp.						×				×						
17. *Tragophylloceras* spp.						×				×						
16. *Polymorphites brouni* .. .									×							
15. *Rhynchonella thalia*..................				×						×		×				
14. *Cincta*				×					×			×				
13. *Rhynchonella* sp. [*rostellata*]				×								×				
12. *Bifericeras tubellum*												×		×		
11. *Polymorphites polymorphus*		×										×	×			×
10. *Bifericeras subplanicosta*	×	×											×	×	×	×
9. *Microceras* spp.	×	×											×	×		×
8. *Cymbites globosus*	×	×										×	×	×		
7 *Deroceras* spp.	×	×	×	×								×	×	×		
6 *Echioceras* spp.	×	×	×												×	×
5. *Oxynoticeras guibalianum*	×															×
4 *Cheltonia accipitris* . .													×	×		
3. *Oxynoticeras oxynotum* ...													×	×		
2. *O. ferrugineum*													×			
1. *O. cluniacense*													×			

[1] The names are those used by Mr. L. Richardson. For remarks on them, see Faunal Notes, p. 69.

(*d*) Consideration of Table I.

The lower line in Table I should indicate the depth of the exposure, and the upper line not necessarily the tops of the various cuttings, for there are superficial deposits in certain cases, but the top of the exposed Lias in them. By horizontal lines are indicated what are lacunæ supposed to be due to stratal failure, and by vertical lines what may be due to some other causes like collection or nomenclature failure.

If we take the Table in descending order, the first point to notice is the absence of a *Beaniceras* fauna (Hwiccian 3), for this fauna occurs only a short distance away to the south, Hewlett's Hill, and the Glenfall, near Cheltenham,[1] and is widely distributed over the Continent.

Two species of *Acanthopleuroceras* (*A. solare* and *A. quadratum*) are recorded from a locality distinct from those which yielded the other *Acanthopleurocerata.* They are of the type which I recorded with a query in my former paper (p. 264) for Leckhampton and Hucclecote on the level of Hwiccian 2, to correspond with Dr. Lang's records of Dorset strata. Mr. Richardson records them at Didbrook with *Liparoceras chelt*[*i*]*ense*: I have entered them in the table as being above it; but definite proof of this is lacking. Whether placed in the table above *L. cheltiense*, or below it, they produce a gap in the records. As this gap is continuous along a line of country, it looks as if stratal failure were the explanation.

The important point is that these species were found separate from the other *Acanthopleurocerata*: the evidence is so far in favour of the surmise made in my paper—that stout *Acanthopleurocerata* occupy a different horizon from that of the *valdani*-like forms.

The record of *Uptonia bronni* and no record of *U. jamesoni*[2] greatly strengthens the surmise made in my paper (p. 267) that there is faunal repetition of *Uptonia*—that there are two waves of *Uptonia* which do not occupy the same horizon: especially as Mr. Richardson says that *U. bronni* was abundant, and that he had found it at other Gloucestershire localities.[3]

Mr. Richardson records a considerable brachiopod fauna: *Cincta* many spp., *Rhynchonella thalia* D'Orbigny, *Rh.* [*rostellata* (Quenstedt)], which is usually taken to indicate the *jamesoni* zone: and therefore their position is now inferred to be in the pre-*bronni* beds.

It will be interesting to consider these brachiopod records in detail. For *Cincta* (*Terebratula numismalis* auctt.) is a genus of wide range: it occurs at Radstock (Somerset) and in Normandy —in both places are fine specimens: there are fair-sized specimens

[1] The following species of *Beaniceras* from near Cheltenham have been figured (II, 4, II, 9):—*B. centaurus*, pl. cxlvi, *costatum*, pl. cxxiii, *crassum*, pl. cxlvii, *rotundum*, pl. cxxix, *senile*, pl. cxxvi; so it is quite a noticeable fauna.

[2] XVIII, 1, p. 139.

[3] *Ibid.* p. 148.

in Dorset, but they are not well preserved; it is so characteristic of the Würtemberg Middle Lias as to have given the name Numismalismergel to a large part of Lias γ. *Rh. thalia* is an unmistakable form: it occurs at several places in the Severn Valley, but is absent from Radstock, very doubtful for Dorset, is common in Normandy, is absent from Würtemberg. The difference in the distribution is to be noted, as raising suspicion whether the strata yielding *Cincta* and the *Rhynchonella* are of quite the same date. The absence of the *Rhynchonella* from Würtemberg might be taken as distribution failure, but its absence from Somerset, though it occurs a few miles to the north in Gloucestershire and reappears to the south in Normandy, is the chief point, for brachiopods flourished at Radstock in the Middle Lias.

Rhynchonella rostellata might be expected to agree in range with *Rh. thalia*, but it does not: it is common in Würtemberg, and fails in Normandy: it is absent from Radstock, and very doubtful for Dorset.

Assistance in investigating the position of the brachiopod fauna would be expected from Quenstedt's 'Der Jura.' He has there, however, in the Middle Lias (Lias γ) an ammonite sequence which has long puzzled me. As it may be a source of trouble to others I am tempted to transcribe the essential part of his table (Table II),

TABLE II.—SUCCESSION IN LIAS (β, γ, *pars*) ACCORDING TO QUENSTEDT.[1]

*Davœi*kalk.	*Ammonites davœi, striatus, lineatus, maculatus.*
Rostige Kalkmergel.	*Ammonites jamesoni.* *Ammonites ibex, polymorphus, maugenestii.* *A. valdani, masseanus, striatus, pettos.* *Terebratula numismalis, rimosa.* *Ammonites centaurus, natrix, heterophyllus, latæcosta, bronnii, caprarius.*
Spiriferenbank.	*Spirifer verrucosus, Terebratula curviceps, calcicosta.* *Ammonites nodogigas, taylori.* *Gryphæa obliqua (cymbium).*
Raricostatenbank.	*A. raricostatus, armatus.*

especially as it can now be seen that his error is, in part at any rate, explicable as due to that faunal repetition of *Uptonia* which I have mentioned above: in fact, his error becomes, to a certain extent, evidence in support of the surmise made in my former paper.

If the part in Table II relating to the ammonites of the Rostige Kalkmergel were to be turned the other way about, it would give more nearly the sequence set forth in my paper. Oppel who, as his 'Juraformation' shows, was a genius in identification of specimens and in correlation of strata, is quite opposed to Quenstedt: he gives the following sequence:—

[1] XV, 1, Table facing p. 293

TABLE III.—ZONAL SUCCESSION ACCORDING TO OPPEL.[1]

Davœibett.
Ibexbett.
Jamesonibett.

Hauptlager der *Terebratula numismalis* placed at the top of the Jamesonibett and *Rhynchonella thalia* given as one of its fossils.

Oppel (p. 165) quotes *Ammonites taylori* with and under *A. jamesoni*, and states that he found it in Northamptonshire.

Quenstedt gives a little more information of the sequence in his later work ('Ammoniten des Schwäbischen Jura' vol. i, 1883–85) which I epitomize thus :—

TABLE IV.—LIAS γ (WÜRTEMBERG) SUCCESSION, AFTER QUENSTEDT,[2] EPITOMIZED.

5. Kalkbank.		*Ammonites davœi.*
4.	Rostige Mergel.	*Ammonites jamesoni.* (May sometimes appear earlier, and is also found above *A. davœi.*)
3.	Rostige Mergel.	*Natrices* [*Platypleuroceras*].
2.	Rostige Mergel.	*Ammonites taylori.* (In the lowest layer of the Numismalis-mergel.)
1. Cymbienbank.		*Ammonites armatus nodogigas.* Small Spirifers.

These tables of Quenstedt are noticed, because they seem to teach some interesting lessons: they show that the interpretation of openings in different places may easily lead to crisscross correlation, especially if there be faunal repetition and also various non-sequences. But also there is nomenclature failure, for he has mistaken species of *Platypleuroceras* for *Uptonia* (*jamesoni*). And the tables show that, when many forms are united under one name, it becomes quite misleading to put them in a stratigraphical table without saying which forms exactly are intended. The greater the generic and specific precision in nomenclature the more exact such tables become and can be made; but, of course, the ideal is to be able to state precisely the position of actual figured specimens: this enables later workers to form their own estimates. From the present point of view, Quenstedt may be said to have missed many opportunities of recording the exact position of his wonderful series of figured Jurassic ammonites,[3] because he did not

[1] XIII, p. 117. [2] XV, 2, vol. i, p. 200.

[3] So far as Jurassic ammonites are concerned, South-Western England (Wessex) is a worthy rival of South-Western Germany (Würtemberg), though the English species have not yet received anything like adequate illustration. In two respects the English Jurassic species surpass the German—one in

realize its importance; but work like that cannot be done all at once, on account of many practical difficulties, and I am now finding just the same fault with my own earlier records: they are not as detailed as could be wished for later work.[1] However, with a map of the country much can be recovered as to the position of specimens by the method of faunal analysis: it is the object of this paper to illustrate that result by the application of the method to a small area.

Some information in regard to the brachiopod problem may be gathered from Dr. W. D. Lang's detailed researches on the Dorset Coast, but this only applies to *Cincta*: specimens of this genus are found, apparently not commonly, and certainly not well preserved. In regard to the Rhynchonellids, the evidence is very doubtful—only two crushed specimens: they look like the *Rh. thalia/rostellata* series; that is all that can be said.

The comparison is given in Table V.

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regard to the Portlandian, where there are many species of which Würtemberg shows nothing—presumably stratal failure; and the other as regards the Inferior Oolite, where there is a fauna many times richer than the German works show, especially in the strata of the hemeræ *bradfordensis* to *zigzag*. In the strata of the stretch of country from Crewkerne to Milborne Wick, about 16 miles, is an ammonite fauna of almost incredible richness and variety. In the plateau which runs from Bradford Abbas about 2 miles eastward there is entombed in the *concavum-discites* zone a fauna not only of ammonites but of other invertebrates, probably without a parallel for richness in the world. And of this area only a few cubic yards have been excavated. The wonderful series of *Sonninia* (*Euhoploceras*) illustrated in my Mon. Inf. Ool. Amm. pls. l, lvii–ciii, from this area are unmatched, if not almost entirely absent from the Continent. This is the more remarkable, because in the same bed with them are Hammatocerata which occur also at Capo San Vigilio (Lago di Garda), Italy, where, however, is no trace at all of *Euhoploceras*. The interesting question whether this is due to stratal failure or to dispersal failure must be left for consideration in a later paper of this series.

Würtemberg also lacks the large Perisphinctids, Aspidoceratids, and Cadoceratids of the Corallian (Argovian), of which there is a remarkable series in the region immediately north-east of Wessex, if not in Wessex itself, rivalling, if not surpassing, the grand series figured by De Riaz from Trept (V, 1). But, so far as English palæontological illustration is concerned, such a series might have no existence—it would be sought in vain.

The agreements and differences in regard to Jurassic ammonite faunas between regions like Wessex and Würtemberg will be an interesting study for the future. At present, not only is publication failure a hindrance, but in many cases too comprehensive generic names prevent the facts from being tabulated concisely.

[1] Collecting inch by inch in thin beds which are condensed epitomes of thick deposits elsewhere is an ideal; but, in dealing with remanié deposits, there is a danger. In such deposits reversal of fauna may have taken place. Thus, it is obvious that if Beds 3, 2, 1 in descending order have been heaved up and are being denuded to form materials for the making of Bed 4, the first specimens to be laid down would be those of Bed 3, and the whole order might be reversed. There is a possibility of the *armatus* bed of Radstock (*leckenbyi*, Raasayan 7), which contains the sweepings of many deposits, showing something of this. There is also a possibility of duplication of faunal horizons occurring under some such circumstances.

Table V.—Middle Lias (Wessexian 7 to Raasayan 4): Gloucestershire and Dorset Coast.

Gloucestershire (L. Richardson).[1]	Dorset Coast (W. D. Lang).[2] *No.*	*Thickness.* *Feet*	*inches.*	*Fauna.*
Bronni Clays of Isbourne. Toddington: Clays with *Rhynchonella thalia.*	118.	8	0	At 3 feet up, *Uptonia bronni* group; *U.* cf. *confusa* (Quenstedt). About first foot. *Rhynchonella thalia?* and *Rh.* cf. *thalia/rostellata?*
	117.	2	0	
	116.	1	0	
	115.	8	0	Top. *U. bronni* group. *Zeilleria.* At 2 feet up, *Uptonia bronni* group. At 1 foot up, *Platypleuroceras* spp. var.
	114.	3	0	*Platypleuroceras.*
	113.	4	0	*Cincta.*
Toddington: Layer with *Cincta* and *Ornithella* [*Zeilleria*].	112.	2	0	
	111.	5	0	*Cincta, Zeilleria, Polymorphites.*
	110.	27	6	Top. *Polymorphites* cf. *mixtus.* Fragments like *U. jamesoni.* Lower part. Fragments, Amm. indet.
	109.	1	0	
	108.	4	0	*Polymorphites peregrinus.*
Toddington: Nodules with *Rhynchonella rostellata.* (Correlation with Dorset uncertain.)	107.	0	9	
	106.	1	0	
	105.	1	0	*Phricodoceras, Deroceras.*
	104.	0	4	*Deroceras leckenbyi.*
	103.	0	4	*Microderoceras lorioli.* Crassicostate *Echiocerata* at the base.
	102.	2	6	
	101.	2	0	
Toddington: *Bifericeras tubellum.*	100.	13	0	At 7 feet and 10 feet up, *Echioceras* cf. *boreale.* At 5 feet up, *Bifericeras tubellum.* Lower foot. *Echioceras rhodanicum.*
	99.	1	0	Crassicostate *Echiocerata.*

In regard to this Table (V), from the *Bifericeras-tubellum* horizon to the base of the *bronni* clays Dorset shows nearly 80 feet, while presumably the Gloucestershire strata are packed away in about a quarter of that thickness—they must lack a good deal, as between *Bifericeras tubellum* and *Uptonia bronni* they disclose

[1] XVIII, pp. 148–151.
[2] X, 1, pp. 306 *et seqq.* Also MS. notes and specimens kindly submitted by him.

none of the ammonites of the Dorset Coast. Correlation of the Gloucestershire layer with *Cinctæ* with the Dorset deposit in Beds 111 and 113 seems to suggest itself; but it is below this that the nodules with *Rhynchonella rostellata* are found. One would suppose that *Rh. thalia* is of earlier date than *Rh. rostellata*—a presumed dwarf development [1]; but the Dorset evidence, such as it is, suggests a later date, and that reading I have adopted for Table I, where it seems to work sufficiently well.

With regard to the brachiopod fauna, the following facts have now been gathered:—

(1) The geographical ranges of *Cincta* and of the two species of *Rhynchonella (Tropiorhynchia)* all vary.
(2) *Cincta* occurs in Dorset between *Platypleuroceras* above and *Polymorphites* below.
(3) Quenstedt and Oppel both place *Terebratula numismalis (Cincta)* on a different level from ammonites, and the Dorset evidence, in part at any rate, supports this.

And to these may be added other facts:—

(4) *Rhynchonella thalia* occurs in Normandy in an area but lately submerged, and with few or no ammonites. It occurs at Sodbury (South Gloucestershire) in strata which follow a prolonged nonsequence: all the strata from Raasayan 2, up to and including Wessexian 5, are missing; therefore it occurs in an area of fresh submergence. It occurs under similar conditions in North Gloucestershire—that is after a period of elevation and erosion, for it may be noted that the record of *Ammonites taylori* for Cheltenham by J. Buckman [2] (*Phricodoceras*, a single specimen), and a similar record of it in Northamptonshire by Oppel,[3] show that, of the missing strata, those of Wessexian 1 (*Phricodoceras*) at any rate were laid down in the Severn-Valley area and beyond, but were almost removed again. The finds may mean pockets of strata or remanié specimens left behind: there is no *Phricodoceras* recorded by Mr. Richardson, so the removal must have been fairly complete.

Considering all these points, I am tempted to make the following suggestion. The brachiopods under consideration lived, not necessarily contemporaneously, but at intervals between the dates of *Platypleuroceras* and *Polymorphites trivialis*: the latter and its allies occur in Würtemberg and widely throughout England; but, what is more important, they fail in Gloucestershire where the brachiopod fauna is found so well developed. I suggest that when these brachiopods lived there was a considerable deepening of the Jurassic sea, marked by overstep in Normandy and Gloucestershire. This deepening of the sea was favourable to brachiopods and unfavourable to ammonites. Ammonites must have lived somewhere during these supposed brachiopod interludes; but it does not follow that the ammonites recorded in the Wessexian scheme are the full sequence, nor that they were the strict contemporaries of the brachiopods: in fact, the evidence seems

[1] A further suggestion as to the affinity of these species is made later, p. 90.

[2] I, 1, p. 91. [3] XIII, 1, p. 165.

decidedly against that conclusion. The ammonites contemporaneous with the brachiopods would, on the theory now propounded, have occupied areas farther in on the Continental shelf; and these ammonite-deposits made in such areas may have been destroyed by successive later erosions when these areas were raised, coincidently with the shallowing of the western sea, after the brachiopod interludes. The brachiopods themselves lend some support to a deep-sea theory—*Rhynchonella thalia* is a comparatively primitive form,[1] with the small foramen which shows that the shell did not live where it had to resist wave-action; while the *Cinctæ* are forms which are also very little developed, and are particularly noticeable for the smallness of their pedicle-opening—a feature more to be taken account of in Terebratuloids than in Rhynchonellids—because, with the former, the pedicle-opening is generally much larger than that possessed by the latter.

Bifericeras tubellum is an interesting little species, which Mr. Richardson has figured in his pl. ii, figs. 29 & 30. Its generic position is perhaps a somewhat rash surmise on my part,[2] though its likeness to the larval stage of *Bifericeras* (*B. parvum*)[3] is noticeable. But this point, which must be a subject for future study, does not affect the interesting problem now presented by the records of this little species. It has not yet been found in Scotland, where *Echiocerata* are so pronounced; it is a Yorkshire form recorded from two beds of blue shale connected with later forms of Echiocerates (*aplanatum* and *macdonnellii*, Raasayan 6, 5); it has been found by Dr. W. D. Lang *in situ* in Dorset, in a layer to itself, between two layers of crassicostate *Echiocerata* (Raasayan 4). and I have specimens from the same locality, position unknown, but in Gloucestershire it seems to be unaccompanied by any *Echiocerata* of the required style, and appears to stand as the sole representative of post-*subplanicosta* Raasayan fauna. These points of evidence are set out in Table VI.

TABLE VI.—STRATIGRAPHICAL RECORDS OF *AMMONITES TUBELLUS*.

Yorkshire.	Gloucestershire.	Dorset.
17. *Ammonites tubellus.*		
18. *Echioceras aplanatum.*		
19.	*Ammonites tubellus.*	
20. *Echioceras macdonnellii.*		
Ammonites tubellus.		
Deroceras aff. *miles.*		
		103. Crassicostate *Echiocerata.*
		100. *Echioceras* cf. *boreale.*
		Ammonites tubellus.
		Echioceras rhodanicum.
		99. Crassicostate *Echiocerata.*

[1] Posteriorly it shows the primitive inverted (that is, dorsally sulcate) norella stage; it is mainly smooth, only having just begun to acquire ribs.

[2] II, 6, p. 70, footnote 1.

[3] II, 4, pl. cxxvii.

If the Dorset and Yorkshire evidence of this table be considered, the first impression is that *Ammonites tubellus* occurs at three horizons—with strong-ribbed *Echiocerata* of *raricostatoides* pattern, with *E. macdonnellii*, and later than *E. aplanatum*. As such repetitive occurrence is quite unusual with ammonite species, much more evidence would be necessary before it could be accepted. Other surmises may certainly be put forward meanwhile; and what seems likely is, that the record of *A. tubellus* in Bed 17 of Yorkshire is due either to nomenclature failure, which is known to have occurred and has been already recorded by me,[1] or to zonalization failure—a mistake as to horizon, for both beds 17 and 20 of Yorkshire are described as 'Blue Shale.'[2]

If the upper record of *A. tubellus* can be disposed of in this manner, then the Yorkshire record might be brought into line with that of Dorset on the supposition that Bed 20 of Yorkshire is an incomplete polyhemeral deposit, containing in its $8\frac{1}{2}$ feet, which is a greater thickness than that of many proved polyhemeral deposits, fragments of Raasayan 3, 4, and 5. But, if that be accepted, it involves the corollary that the number of sequential faunal episodes in Raasayan 4 is greater than has been supposed, and that some of these episodes are missing from Yorkshire.

It certainly seems as if the multiplication of faunal episodes, with consequent non-sequences in various areas, is assuming undue proportions. But, as I remarked in my former paper,[3]

'It is unlikely that the remarkable sequence disclosed at Raasay with the large adjustment which it involves will be the only discovery of its kind.'

And the future may show that, instead of being too bold, I have actually been too timid in dealing with the evidence of Raasay itself. However, the evidence of the dissimilar faunas of other areas will show what further adjustment is required. The important point is to record the evidence, and to give it unprejudiced consideration.

If, then, the supposition about the record in Bed 17 of Yorkshire can be confirmed, and that about the character of Bed 20 be accepted, the faunal sequences may be numbered so as to separate the various episodes. Then it might be possible to present the records in the following manner (Table VII), which brings *Ammonites tubellus* into line without doing any violence to the evidence, except in regard to that of Bed 17.

The Gloucestershire evidence is particularly instructive: it seems to indicate that there was an episode of *Ammonites tubellus* distinct from that of strong-ribbed Echiocerates, which again is to a certain extent confirmed by the order in which Dr. Lang finds these faunas preserved in Bed 100 of the Dorset Coast. There was, in Gloucestershire, entombment of *Ammonites tubellus* and presumably preservation of its strata: just before and just afterwards there is faunal failure. This faunal failure is presumably

[1] II, 6, p. 70, footnote 1. [2] *Ibid. loc. cit.*
[3] II, 8, p. 263.

TABLE VII.—REVISED CHRONOLOGY RELATING TO *AMMONITES TUBELLUS.*

Raasayan.		Yorkshire.	Gloucester-shire.	Dorset.
aplanatum	6.	18. *Echioceras aplanatum.*		
macdonnellii	5.	20. *Echioceras macdonnellii.*		
raricostatoides ...	4*e*. Crassicostate *Echiocerata.*			103. Crassicostate *Echiocerata.*
	4*d*. *Echioceras*, cf. *boreale.*			100. *Echioceras* cf. *boreale.*
	4*c*. *Ammonites tubellus.*	20. *Ammonites tubellus.*	*Ammonites tubellus.*	100. *Ammonites tubellus.*
	4*b*. *Echioceras rhodanicum.*			100. *Echioceras rhodanicum.*
	4*a*. Crassicostate *Echiocerata.*			99. Crassicostate *Echiocerata.*
bispinigerum	3.	20. *Deroceras* aff. *miles.*		96. *Deroceras miles.*

due to stratal failure; and, whether the stratal failure is due to penecontemporaneous erosion or to depositional failure, the *A.-tubellus* episode remains just as distinct.

That *Ammonites tubellus* has not been found in Scotland, where the Echiocerate sequences are so conspicuous with their abundant faunas, might be accounted for on the principle of dispersal failure—that *A. tubellus* had a restricted range. And the same might be said of the lack of this species from Continental records. But this plea is somewhat discounted by the absence of the species from Radstock (Somerset), intermediately situated between Gloucestershire and Dorset—a locality where the Echiocerate faunas are very conspicuously developed.

If, however, *A. tubellus* marks a distinct episode—possibly a time of deep sea, with which the larval character of the species would accord, then the absences from other areas might come into line with that from Radstock and be attributable to stratal failure, presumably caused by penecontemporaneous erosion. In any case, it will be necessary to analyse the Echiocerate faunas more precisely, in order to ascertain which species are pre- and which post-*tubellum*—a long task that cannot be undertaken now, but one promising interesting revelations. It is also desirable to confirm the position of *A. tubellus* in Yorkshire.

The descending sequence *subplanicosta*, *densinodus*, armatoids, Echiocerates, is that which I suggested in my former paper, p. 268. In the three southern cuttings this sequence shows no lacunæ, which is reasonable evidence for its correctness,[1] and, as regards the sequence *subplanicosta*, *densinodum*, *Echioceras*, this is established; for Mr. Richardson records it at Bayliss Hill.

Stratal failure may account for the absence of the armatoid

[1] The lacuna of Bishop's Cleeve has already been commented upon (p. 70).

horizon from Weston Subedge and Bayliss Hill. The same explanation has more reason on its side to account for the absence of the Echiocerate and '*guibalianum*' [*Gleviceras*] faunas from the cutting immediately south of Bayliss Hill; for this lacuna is to a certain extent >-shaped, and stratal failure requires lenticular lacunæ: the southern part, on this theory, is unexposed. The absence from these cuttings of the *biferum* fauna supports my separation of its horizon from that of *oxynotum*. I surmised it as belonging to a level immediately below *oxynotum*, and it might be argued that none of the cuttings reached the level required to find the *biferum* fauna. Yet this fauna is found at Aston Cross, near Tewkesbury, as I recorded in my former paper—a locality about 3 miles to the north-west of the nearest part of the line under review, and at a very considerably lower level of ground: presumably the result of folding and faulting. And this fauna is widespread—extending to Würtemberg. Against the argument that the cuttings did not go low enough, and in favour of an argument of local stratal failure or non-sequence, is the occurrence of the Rhone-Basin species *Oxynoticeras cluniacensis*.[1] Assuming this to be even approximately determined, I judge it to have the character of a species belonging to the *Gagaticeras* horizon (Deiran 1), while the so-called *Oxynoticeras ferrugineum* may possibly indicate the *simpsoni* horizon.

(*e*) The Gloucester Fauna, especially *Schlotheimia*.

Very curious evidence in connexion with stratal and other failures comes from Mr. Richardson's second paper, giving a list of the fauna found on a spoil-heap resulting from excavations at the Gloucester Gas-Works. Mr. Richardson says that

> 'the faunal contents of the beds are similar to those of the equivalent deposits seen in certain of the railway-cuttings' (p. 154);

and, in a way, that is correct. But there is one great feature of difference in the ammonites, namely, eight species of *Schlotheimia*[2]—small forms, more or less allied to *Schl. lacunata* (J. Buckman), and there is one more which he has missed: not one of these is recorded from the railway-cuttings; and this faunal dissimilarity is a very special feature which requires explanation.

The position of these small *Schlotheimiæ* I judged to be about Mercian 7 (*denotatus*), on these grounds:—the original of *Ammonites fowleri* J. Buckman 1844,[3] identical with or very close to *A. denotatus* Simpson 1855,[4] is attached to a Lias nodule from Lansdown, Cheltenham, in which are many specimens of small *Schlotheimiæ*. A similar nodule said to have been found at the foot of Dowdeswell Hill, east of Cheltenham,[5] which geologically

[1] VI, 1, pl. xxv, figs. 8 & 9.

[2] These have been described and figured in II, 2, No. 78, and II, 3. Several of the types are from this Gloucester excavation.

[3] I, p. 104, pl. xii, fig. 7; II, 2, No. 37, 1904.

[4] II, 4, No. 67.

[5] I, p. 105.

is quite impossible, but may be explicable as a treasure lost from some geologist's bag on his road home,[1] obviously came from the same place as *A. fowleri*, and might almost be a part of that specimen's nodule: it shows many small *Schlotheimiæ*.

Now, on the fact of this association of *Schlotheimia* and *A. fowleri*, the presence of small *Schlotheimiæ* was regarded as evidence on which to record a *denotatus* fauna. But Mr. Richardson makes no mention at all of any such ammonite—neither *fowleri*, *denotatus*, nor any *Arietites*. The ammonites that he records with the *Schlotheimiæ* are:—

(11) *Polymorphites polymorphus*,
(8) *Cymbites globosus*,
(7) *Deroceras bispinatum* Hug (armatoid),
(4) *Cheltonia accipitris*,
(3) *Oxynoticeras oxynotum*,

with *Cymbites* cf. *personatum* Simpson, which may be placed with 8: it is presumably a development of *C. globosum* and a heterochronous homœomorph of *Ammonites personatus*, which is a dwarf *Agassiceras*[1]: that belongs to a much lower horizon (Lymian 6).[2]

I have numbered these records to correspond with those in Table I, facing p. 70, so that it will be seen that there are missing any representatives of the *subplanicosta* and *densinodus* faunas (10, 9)—also of the 1st *Echioceras-Gleviceras* fauna (6, 5). These appear to indicate stratal failures (non-sequences) in the Gloucester deposit. Dispersal failure can with difficulty be put forward to account for the absence of the *subplanicosta-densinodus* fauna over an area of a few square miles or less. For, not only is this fauna fairly widespread—from Würtemberg to the Hebrides, but it is in good evidence at Cheltenham, about 8 miles to the north-east, and at Standish near Stonehouse (Gloucestershire), about the same distance to the south of the locality under consideration. But, if dispersal failure could not be called in to account for such a purely local absence, stratal failure could justly be assigned: for such failure in quite short distances—even in a few yards—has been proved often enough.

However, in the present case another cause seems to give a better explanation—nomenclature failure: that the *Polymorphites polymorphus* is not the same species as that found in the railway-cuttings, but is the same species as that quoted by Mr. Beeby Thompson from the *Oxynotum* zone of Warwickshire.[3] This species is, in part, at any rate (for he kindly gave me examples), the *Ammonites electre* Reynès, one of those phylogenetically immature species whose generic position is doubtful, because it has not arrived at the stage of developing any special characteristics. But the

[1] Ejecta from geologists' bags, sometimes accidental, sometimes on purpose to lighten a load, have been traced before now as the actual cause of strange and geologically very incorrect records.

[2] See later, p. 91. [3] XX, 2, p. 71.

generic position is not of importance now. What is important is the recognition at, presumably, two horizons of two species sufficiently alike to cause nomenclature failure and yet sufficiently distinct for separation.

If this supposition be correct, this '*Polymorphites polymorphus*' indicates a horizon about 3, and the failure of the *subplanicosta-densinodus* faunas is to be accounted for by the excavation being started below their position—exposure failure.

It is doubtful, however, whether any such explanation will account for the absence of the *Echioceras-Gleviceras* faunas (6, 5); and it certainly will not account for the absence of the *biferum* fauna, which should intervene between *oxynotum* and the *Schlotheimiæ*: in that case, at any rate, stratal failure would appear to be the explanation.

Now the occurrence of the *Schlotheimiæ* at Gloucester might be explained by saying that the excavation had reached a lower level than in any of the railway-cuttings; and the absence of *A. fowleri* as due to this excavation not having gone deep enough to reach the line of nodules (exposure failure), or to absence of the nodule stratum (stratal failure). This theory means that the *Schlotheimiæ* occur at two horizons—in an upper horizon (clay) by themselves, in a lower horizon (argillaceous limestone) associated with *Arietites* (*A. fowleri*).

Before discussing it we may consider the possibility of collection failure. Mr. Richardson says (*op. cit.* p. 154):—

> 'This clay was heaped up . . . to be used for brickmaking or any other purpose.'

From clay destined for brickmaking nodules are picked out, and thrown aside separately. That might possibly explain the absence of any *Arietites*. Yet it is rare for all nodules to be picked out at the first moving, and, again, an experienced geologist like Mr. Richardson would not overlook the nodule heaps. Even supposing overlooked nodules, th s does not necessarily disprove a theory of two horizons. For, what does that theory involve? Among my father's Cheltenham specimens of *Ammonites lacunatus* (*Schlotheimia* spp.) there are examples from two matrices—a clay matrix and a limestone matrix. If only the *Schlotheimiæ* of the clay matrix have been found at Gloucester, and if they occupy another horizon and are distinct from those of the limestone matrix, then there ought not to be any of the limestone species at Gloucester, if the nodular horizon is missing.

There are three successive waves of *Schlotheimiæ* in the Lias (faunal repetition), not counting some species of isolated position. The lowest, a series of large forms, some of them quite giants, lived in late Hettangian (Hettangian 8) and finished off in early Sinemurian (Lymian 1). They occur widely over Europe, from the North-Eastern Alps and Würtemberg to Dorset, Somerset, and Yorkshire.

The second wave consisted of comparatively small forms repre-

sented by the species named by my father as *Ammonites sulcatus*[1] (now *Schlotheimia sulcifera*[2]), *Schl. jugata* S. Buckman, and *Schl. miscella* (Oppel).[3] Their date has been supposed to be *Arnioceras* (Lymian 7); but, as they do not occur in other areas where the *Arnioceras* fauna is common, it may be suggested that strict contemporaneity is doubtful, and again two faunal horizons are possible. They have been found only in a very limited area: which does not mean that their dispersal was at fault, because the explanation is possibly stratal failure—their deposits destroyed by one of the many Jurassic erosions. Gloucestershire is the only locality for the forms above mentioned,[4] but what I adjudge as similar, possibly contemporaneous forms, though not identical species, are some of these small *Schlotheimiæ* from the Lias of Spezia (Italy),[5] *Schl. lacunoides* of Würtemberg,[6] *Schl. compta*, *Schl. ventricosa* (Sowerby, Canavari), *Schl.* cf. *lacunoides* (Quenstedt) quoted from Yorkshire,[7] and those specimens which Dumortier calls, I presume incorrectly, *Ammonites lacunatus* and places below the *stellare* horizon (Mercian 6). His figured *A. lacunatus* (*Schl. deleta* Canavari) belongs to the next wave.

This third wave of *Schlotheimiæ* consists of a very considerable number of quite small, generally fine-ribbed species, of which *A. lacunatus* J. Buckman is the most quoted example, the date of which, now under consideration, is with or later than *denotatus* (Mercian 7), but pre-*Gagaticeras* (Deiran 1). These species occur over a considerable area of Europe: for *A.* (*Schlotheimia*) *lacunatus* has been claimed, though not always quite correctly identified, for Italy, Hierlatz, Würtemberg, the Rhone Basin, and England (Gloucestershire); and with allied species, one identified with a Hierlatz species, the range extends to Yorkshire. It is this range which is the subject of the subjoined Table VIII (p. 84), together with that of involute *Arietites* of *denotatus* pattern.

The first point to be noticed in this analysis is that the *Schlotheimiæ* of the third wave occur in Italy, at Hierlatz, and at Gloucester—localities which show no *Arietites* indicative of *denotatus* (Mercian 7), and that they do occur in Würtemberg, at Cheltenham, and in Yorkshire—localities which do show *Arietites*. The absence of *Arietites* from certain places is the point to explain. Italy and Hierlatz, it might be urged, are beyond the range of these *Arietites*; and, for Gloucester, collection failure might be put forward, as already remarked. But Quenstedt supplies evidence that there are two horizons—one of *Arietites* and one of *lacunatus*,

[1] II, 2, No. 39. [2] II, 4, p. 38 *b*. [3] II, 2, No. 39, note.

[4] The strata from this horizon in Gloucestershire suffer from exposure failure: they have not been properly uncovered since the making of the Bristol–Birmingham Railway in the 'forties.

[5] Two of these Spezia species are said to come from the *marmorea* and *rotiformis* zones of the North-Eastern Alps (XXII, pl. xxi, fig. 6, & pl. xxii, figs. 1–2), but the identifications do not seem quite satisfactory.

[6] II, 3, pp. 240, 241.

[7] II, 6, p. 99: entered with the third wave; but it may be earlier.

Table VIII.—Distribution of *Schlotheimiæ* (Third Wave) and *Arietites* (*denotatum* Series).

		Yorkshire.	Gloucester.	Cheltenham.	Rhone Basin.	Würtemberg.	Hierlatz.	Italy.
Schlotheimia lacunata Series.	*Schl. parva* (heautotype)...	...	×					
	Schl. deleta	...	×	...	×	...	...	×
	Schl. substriata	×	×					
	Schl. lacunata	...	×	×	...	×		
	Schl. rumpens	...	...	...	..	×		
	Schl. cheltoniensis	...	×	×				
Schlotheimia glevensis Series.	*Schl. subdeleta*	...	?	×				
	Schl. glevensis	...	×					
	Schl. glevensis/larvalis ...	...	×					
	Schl. larvalis..................	...	×					
Schlotheimia subpolita Series.	*Schl. parva* (holotype)......	...	...	×				
	Schl. subpolita	×	...	×				
	Schl. angustisulcata	×	...	...	...	...	×	
	Ægoceras sp.	...	...	...	...	...	×	
	Schl. geyeri	...	..	...	...	...	×	
	Schl. sulcata (Simpson) ...	×						
Arietites.	*Arietites impendens* & aff.	×	...	...	...	×		
	A. fowleri	...	...	×				
	A. denotatus & aff.	×	...	...	...	×		
	A. radiatus & aff.	×	...	...	...	×		

for he places the former in the Beta-Kalk [1] and the other as above that.[2] It might be objected that Quenstedt is not necessarily reliable, in view of what has been said above (p. 72); but confirmation is to be found in Pompeckj, who places *Schlotheimia lacunata* in the *Oxynotum* zone.[3]

Turning now to the evidence as between Gloucester and Cheltenham, there are two species with limestone matrix [4] (*Schl. parva*, *Schl. subpolita*), of which the second is absent from Gloucester, and the first may be an identification insufficiently precise; at least, the holotype from limestone of Cheltenham has ribs which are almost straight on the lateral area, and the

[1] XV, pp. 146, 151, *Ammonites impendens*.
[2] *Ibid.* pp. 165, 166.
[3] XIV, 1, p. 89.
[4] II, 2, p. 78 *a*.

heautotype from clay of Gloucester has ribs which show a distinct flexure. This point need not be laboured: it is only mentioned as something to be on guard about in the future; especially as an almost identical straight-ribbed form is figured by Geyer from Hierlatz.[1]

Another Hierlatz species, *Schlotheimia geyeri*, has much of the character of *Schl. parva*. Two other species, *Schl. angusti-sulcata* Geyer, *Schl. sulcata* (Simpson), are closely allied to *Schl. subpolita*: the first being recorded from Hierlatz and Yorkshire.

These species have much in common. and form what may be called the *subpolita* group, fairly separable from the *lacunata* group. But, if the characters of the *subpolita* group indicate those forms which lived during *denotatus* time, why are they absent from the Beta-Kalk of Würtemberg, seeing that they range beyond that country? It is a legitimate point for enquiry, and the first speculation which arises is this—Are there three horizons? thus:

(a) *lacunata*,
(b) *subpolita*,
(c) *denotatus*.

I am not claiming that there are; but attention must be called to this possibility, for the purpose of precision in records. It is safer to work with too many than with too few horizons for recording purposes: thus, it is better to keep the *subpolita* and *denotatus* records separate, where the one occurs without the other.

The surmise of three horizons would involve two suppositions:—

(1) That the Würtemberg strata are deficient in something—show a non-sequence—between the Beta-Kalk and the *lacunatus* clays; (2) that the association at Cheltenham of *subpolita* in nodules with *Arietites fowleri* is due to paucity of sedimentation, which has made what should be a sequence look like contemporaneity of deposit.

If these suppositions could be substantiated, and they are put forward in the hope that work in the field, especially in Yorkshire, may succeed in yielding evidence, then there would be a possible explanation of the absence of the *subpolita* fauna from the Beta-Kalk of Würtemberg and the absence of *Arietites* of the *denotatus* pattern from Hierlatz and Spezia (Italy).

On the basis of three horizons this position would be reached as regards the faunas of Cheltenham and Gloucester. The former shows faunas of all three presumed horizons: a clay with the species of the *lacunatus* group, a nodular limestone—a condensed deposit—containing the *subpolita* and *Arietites* faunas, in juxtaposition. The Gloucester deposit, on the other hand, has yielded only the fauna of the *lacunatus* group, and has not revealed the faunas of the nodular horizon because there has been collection failure, exposure failure, or stratal failure.

[1] VIII, pl. iii, fig. 21, *Ægoceras* sp. ind.

The reason for inferring that there are faunas of two dates in the nodular band is the difference in the geographical distribution of those faunas on the Continent; but it may remain only a working hypothesis for the present, to prove or disprove which further evidence should be collected.

III. Additional Enquiries.

(*a*) The Hierlatz and Spezia Faunas.

The faunas of these areas have been regarded as 'mischfaunas' and dwarf faunas. As they come considerably under review in connexion with the faunas of the Gloucestershire deposits, it seems appropriate to enquire further concerning them, especially in order to see whether it is in regard to the preserved strata, or in regard to the preserved fauna, or in regard to both, that they are exceptional.

The strata of Hierlatz and Spezia give the impression of being what may be called highly-condensed deposits, after the pattern of the Junction Bed of the Dorset Coast, which in about 2 feet represents, with many lacunæ, what is found distributed through hundreds of feet of strata elsewhere; and it gives, at first sight, the appearance of being one bed—with a 'mischfauna'. The Hierlatz and Spezia deposits are, perhaps, a still more exaggerated instance, complicated possibly also by much redeposition of specimens. A technical term for such deposits seems to be required—deposits in which condensation, whether produced by paucity of sedimentation, or by penecontemporaneous erosion, or by both combined, has produced the false appearance of contemporaneity.

At Wellow near Radstock (Somerset) there occurs, as has been already recorded,[1] a bed of ironshot rock, a hand-specimen of which yielded *Hildoceras bifrons* and *Acanthothyris spinosa*—the names being used in a wide sense: that is, a species of Whitbian (7 [b]) and a species of Vesulian (*garantiana*). Between these two ironshot deposits, which show but little difference from one another, are to be found, within the radius of a few square miles, some hundreds of feet of strata deposited during three Ages and some 26 hemeræ. The gradual disappearance of the intermediate strata by erosion can be traced from place to place; so that, when the climax is reached at Wellow, and the two ironshots coalesce into one block, the phenomenon is so much in accordance with anticipation that it does not excite the astonishment which is its due. But, let us suppose such coalescence to occur over a fairly-wide extent of country; and let us imagine that all the other strata which yield the clue had been removed, with strata of the Wellow type as the only Lias-Oolite deposit remaining, then we should doubtless point it out as a good instance of a mischfauna, citing, as Geyer does for Hierlatz,[2] the fact of the different

[1] III, 1, p. 712. [2] VIII, 1, p. 278.

species being found in contact as a proof of their contemporaneity. But experience of this and of many other cases has shown that the finding of specimens in the same block of rock, however closely they may be in contact, is no proof of contemporaneity; therefore Geyer's insistance on this point makes no impression. Seeing is not believing in such cases, and scepticism about contemporaneity is always advisable: faunal analysis will soon detect the false cases.

The Wellow example is interesting, because of the great similarity of the two matrices which coalesce—in other cases, some difference of matrix may excite suspicion. But I think that the Wellow case with its coalescence of like matrices goes a long way to explain the Hierlatz fauna, allowing for the Hierlatz case possibly several non-sequences and a good deal of redeposition.

Looking at the Hierlatz ammonite fauna as figured by Geyer[1] I judge the main of the comparable species to represent the following dates:—

Raasayan 3,	*bispinigerum*,
Raasayan 1,	1st *Echioceras*,
Deiran 2,	*simpsoni*,
Deiran 1,	*Gagaticeras*,
Mercian 7 [b],	*subpolita*,

with certain derived species from lower horizons like Lymian 7 (*Arnioceras*). Thus, so far as Raasayan 1 and Mercian 7 [b] are concerned, Hierlatz may be compared with the Gloucestershire deposits described by Mr. Richardson.

Much the same explanation may, I think, be applied to any supposed admixture of species of different dates in the strata of Spezia; but, with one or two exceptions, the fauna of that area is not comparable in date with those now under consideration from Gloucestershire.

(*b*) Concerning Small and Large Ammonites.

The series of small ammonites yielded by the strata of Hierlatz and Spezia suggest at first sight the idea that these localities show dwarf Ammonite faunas of Liassic date at times when other localities show faunas of large forms. This, I think, states a general opinion, to which there would be a necessary corollary—that the seas in which the small forms lived were more or less separated from the seas of other areas, and were in some way unfavourable to life. This would again involve a special delineation of palæogeographical cartography, showing more or less landlocked seas with restricted outlets. Now the work that has been done in my former paper and to a certain extent in this one, suggests that all this superstructure may rest on a very insecure foundation or on no foundation at all. The small forms of Hierlatz and Spezia would not be comparable with the large forms of other Liassic areas, unless they were actually synchronous with them. In other

[1] VIII, pls. ii–iv.

words, the difference of size may not be geographical but chronological.

For instance, the former correlation of the Gloucestershire strata yielding small *armati* with the Radstock strata furnishing giant *armati*—the placing of both deposits as *armatum* zone—involved the opinion, implied if not actually expressed in so many words, that the small *armati* of the former were either dwarf forms of, or merely the inner whorls of, the large forms of the latter area. Now, the stratal sequence of Raasay, combined with results from other areas, has shown that the deposits with small *armati* are separated from those with the large forms by a time-interval expressed in some 300 feet of deposit.[1] In Gloucestershire are found preserved, not far above *oxynotus* beds, the strata with the small *armati*, which are now known to be the lower horizon, while the upper horizon fails. Only a few miles away to the south, but contiguous to the Mendips, at Radstock, are preserved strata (in about the same position with regard to Oxynotoids) yielding the large *armati* which are now known to be the higher horizon; and here the lower horizon has not been preserved. Thus, the difference between these two faunas of small and large ammonites is chronological, not geographical, and the difference in the relative preservation may be said to be geological—it is an accident of diastrophism that strata of the date of small forms have been preserved in Gloucestershire, and not the strata with the large forms; while the reverse happens to be the case in North Somerset.

This seems to give, in part, at any rate, a clue to the Hierlatz and Spezia faunas; but, in order to consider them properly, and to compare them with faunas of other areas, it becomes necessary to have a technical nomenclature: because different causes produce the small ammonites which may be represented in palæontological works or collections. Further consideration shows that the term 'small ammonites' covers a whole series of phenomena, and, that any investigation of a dwarf or small fauna, which at first sight might be thought a simple proposition, is really quite complicated.

The condition in which ammonites are found fossil may differ materially from their condition when alive. In opposition to the cases in which specimens occur usually only as inner whorls (and those inner whorls by no means all the air-chambers) are those cases like the Acanthopleurocerates of the Gloucestershire Lias and the capricorns of the Dorset Coast, of which as a rule only the body-chambers are found; the air-chambers are seldom preserved or, if found attached to the specimens, are crushed flat. Compression to flatness of a greater or less portion of the inner whorls of serpenticones is quite common, and the loss of this part in extraction, leaving only the outer whorls—body-chamber and some air-chambers—is the general result. It all depends on how many of the air-chambers could be filled with deposit before fossilization.

[1] II, 8, p. 267.

It has, then, to be considered that the specimens as found fossil do not properly represent the conditions of existence, from various reasons which it may be advisable to set out in the following manner:—

1. Fossilization failure—specimens may be damaged and reduced in size before entombment, or may be incompletely fossilized from various causes.
2. Preservation failure—specimens may be destroyed after fossilization.
3. Extraction failure—the specimens as extracted may not properly represent the specimens as entombed.

Concerning 1 (fossilization failure), this covers ammonites which have lost body-chamber or more through damage before entombment, as by breakage in connexion with redeposition, or may have lost air-chambers through incomplete fossilization. The loss of a crushed remnant of air-chambers may also be due to extraction failure—the rough method of clay-digging in a brickyard would mean loss of such air-chambers, with the result of only body-chambers being found. Body-chamber specimens may then be regarded as a combined result of fossilization and extraction failures.

Preservation failure (2) is to be distinguished from fossilization failure, in that it is the loss of specimens after entombment, as, for instance, from chemical causes. But this could not be pleaded as a reason for faunal failure, if contemporaneous species of the same family were preserved.

Extraction failure (3) is a common cause in regard to ammonites in making the collected specimens unrepresentative of the entombed specimens, and still less of the living specimens. In reality, it is of course not so much extraction failure as imperfect extraction. In working with a hammer at the face of a section the extraction of complete ammonites becomes almost impossible, with the result that only the inner whorls are recovered—especially if the specimen be one with whorls not greatly overlapping. Thus the extracted and figured species of *Pseudogrammoceras* from the Cephalopod Bed of the Cotteswolds do not in many cases represent the full size of the living species by a whorl or more [1]: destruction of the outer whorl before fossilization is in some cases the cause of this, but destruction of it during extraction is also in a great measure responsible.

To these causes of incorrectness in regard to fossil evidence may be added another which has already been mentioned—namely, zonalization failure (p. 78), attribution of the fossil to a date other than that of the living specimens, either from inaccurate collecting, incorrect stratigraphy, wrong record of stratum, mistakes in labelling, and various other accidents with which palæontologists

[1] See S. S. Buckman, 'Monogr. Inf. Ool. Amm.' pl. xxxiii, fig. 17, pl. xxxiv, fig. 3, & pl. xxxv, fig. 4, for examples

are already fully acquainted; and publication failure[1]—species have been collected, but have not yet been figured, described, or otherwise given publicity.

The foregoing remarks will have shown that there are two classes of small ammonites, which may be tabulated as under:—

I. Ammonites which are small as a matter of growth: these require further analysis.

II. Ammonites which are small examples with air-chambers, because they have been reduced by geological accidents of deposition, or by accidents of extraction, or by both causes.

In 'Type Ammonites',[2] I have proposed a series of technical terms for the different sizes of organisms:—

Colomorph—small, because reduced by breaking-off of the outer portion by geological or artificial agents.

Micromorph—small by growth—Hudleston ('Jurassic Gasteropoda'[2] Pal. Soc. 1888, p. 61) subdivided into:—

Brephomorph—small, because young—baby stage.
Anamorph—small, because phylogenetically immature.
Phaulomorph—small, because stunted, but phylogenetically mature.
Catamorph—small, because phylogenetically degenerate.

Nomomorph—of normal or customary size.

Megalomorph—of large size—giant stage.[3]

Objection might be taken that these terms are insufficient in number to meet all the requirements which a detailed analysis could show; but for the present argument they should suffice, and a few words may be said to illustrate them.

The former correlation of the Gloucestershire and Radstock *armatum* beds mentioned above involved the supposition that the Gloucestershire *armati* were either colomorphs or phaulomorphs of the Radstock species. They may be colomorphs; but, not being of the same date, they would be colomorphs of other species. They are doubtfully phaulomorphs, for such forms are rare in the Lias: they are presumably, being earlier in date, anamorphs—species small because they have not reached their full phylogenetic development. They may be colomorphs of anamorphs—specimens reduced in size geologically or artificially.

The rarity of phaulomorphs in the Lias—at any rate, until quite a late period—is an interesting fact; but, now that the phenomenon is recognized, others may be detected. At present there occur to mind the following:—In the Hettangian, *Psiloceras brevicellatum*

[1] See II, 8, pp. 278, 311. [2] II, 9, p. 6.

[3] These terms may help to an understanding of the problem of *Rhynchonella rostellata* and *Rh. thalia*. The former may not be a dwarf development (a catamorph) of *Rh. thalia*; but may be a development of the same stock (a phaulomorph of genus *Tropiorhynchia*); or *Rh. thalia* may be the megalomorph of its genus, though not a megalomorph so far as the family (Rhynchonellidæ) is concerned. At any rate, if *Rh. rostellata* is not a catamorph of *Rh. thalia*, it does not need to be later in date: *Rh. thalia* may be the later. This agrees with the Dorset-Coast evidence—such as it is, and seems to fit the Gloucestershire analysis (Table I, facing p. 70).

Pompeckj, and '*Ammonites angulatus*, young shell,' Wright,[1] a Schlotheimian phaulomorph; in the Lymian, *Ammonites personatus*, an Agassiceratan phaulomorph, with *Agassiceras spinaries* Quenstedt, and other like forms as nomomorphs. *Agassiceras halecis* J. Buckman is, presumably, a brephomorph; and some other species of *Agassiceras* are anamorphs. In the Deiran, *Cheltonia* is a phaulomorph; its nomomorph is *Oxynoticeras oxynotum*, which, however, is usually found much broken down—only as air-chambers—truncated nomomorphs, or so much reduced as to be quite small—colomorphs. Occasionally, specimens about 6 times the usual size are reported, which is in accordance with expectation; for it makes *Oxynoticeras* agree better with its allies, *Gleviceras* [2] and *Radstockiceras*.[3]

In the Domerian, *Amaltheus lævis* (Quenstedt) is obviously an Amaltheid phaulomorph.

The foregoing statements about phaulomorphs refer, not only to British, but to the Continental Lias generally. However, in the Middle Lias of Italy are two peculiar genera which certainly have the appearance of being phaulomorphs—*Diaphorites* and *Pimelites* Fucini,[4] (*Præsphæroceras* Levi).[5] Their family position is doubtful—Phylloceratidæ according to Fucini, Dactyloidæ according to Hyatt. The strange suture-line with a much extended superior lateral lobe seems to have some resemblance to that of *Gagaticeras*,[6] so it seems to me possible that they are phaulomorphs of the Liparoceratidæ.

In the Inferior Oolite phaulomorphs abound—incipient scaphiticones, with considerable development of lateral auricles—*Otoites*, *Normannites*, and *Cadomoceras* may be cited as examples: here publication failure comes in—there are many new and strange forms yet to be figured.[7]

The largest megalomorph ammonites occur in the Jurassic at two periods, near the beginning and towards the close—Lower Lias and Portlandian. In between, the times of Inferior Oolite (Bajocian–Vesulian) and Corallian (Argovian) show some good megalomorphs; but few attain such gigantic size as do the species of the earlier and later dates.

A considerable number of megalomorph ammonites must be extracted from the quarries and other excavations in this country every year, and be almost wholly lost to science. Should they escape the sledge-hammer of the quarrymen, they may find a temporary home on some rockery, to be destroyed by frost in a few years or broken up for road-metal on a change of occupiers. Rarely, they may be rescued from the quarryman or the rockery by the geologist; but even then their safety may not be assured—not

[1] XXIII, pl. i, fig. 5 only.
[2] II, 8, p. 289; p. 291, 450 mm.
[3] *Ibid.* p. 287; 380 mm.
[4] VII, pp. 234, 236 & pl. xxv.
[5] IX, p. 275.
[6] II, 4, pl. lxxviii, fig. 3.
[7] *Trilobiticeras* has been figured since this was written (II, 9, pl. cxl). There are many species of this genus—all new.

even if they have been figured in scientific literature, and found their way to a museum. The type of *Ammonites bucklandi* is said to have been discarded from its museum, relegated to a rockery, and lost. It can hardly be this type which Buckland carried like a French horn (as described by Sowerby),[1] because for such a purpose inner whorls to at least a diameter of a foot must be missing, and the type, if 2 feet in diameter, shows no more than 6 inches diameter of lost whorls. Presumably, then, another historic specimen of the Buckland collection has shared the same fate.

In between those four principal dates of such megalomorphs are times when micromorphs held sway, the variations in size following each other in a wave-like manner.[2] But this opens up a subject of wide interest that may lead us away from the purpose of this paper. Sufficient has been said to show, it is hoped, the advantage and applicability of these technical terms: it is time to return to the subject in hand.

The questions to be asked concerning the Hierlatz and Spezia faunas are—how many specimens are colomorphs, and how many species are micromorphs? For, if certain specimens are colomorphs of species which are really nomomorphs, their small size may be said to be something of a natural accident, and no argument for a small fauna can be based on them. Some specimens certainly are colomorphs. Then there are other small specimens identified with species which are fairly large (nomomorphs) in other localities—are they also colomorphs, or are they really micromorphs, and, if the latter, are they brephomorphs or phaulomorphs?

Considering how unreliable is the identification of Liassic nomomorphs in, say, the family Arietidæ, and how little is known about the inner whorls—the juvenile stages—of species supposed to be familiar, one may perhaps be forgiven for expressing considerable doubt about any identifications of small forms with species only known by fairly large examples. But, supposing these questions satisfactorily disposed of, and that there still remains a micromorph fauna—anamorphs like *Cymbites* and catamorphs like species of the two later waves of *Schlotheimia*, then, before deciding that this micromorph fauna is special to particular areas, it is necessary to enquire precisely as to the dates which it represents and to see whether at such dates micromorph faunas existed elsewhere.

The phenomenon of small forms was, at certain dates, of European extension: Hierlatz shares it with Gloucestershire; in fact, Gloucestershire would show a larger series of small forms than Hierlatz, for the deposits which happen to have been preserved there are those of the times when ammonites were mainly small, and the deposits have a longer range in time than those of Hierlatz. From Mercian 7 to Wessexian 1, a period of, say, possibly some 21 hemeræ, about half were dates when ammonites did not exceed

[1] 'Mineral Conchology' vol. ii (1816) p. 69.
[2] See, for partial illustration, Table X, p. 95.

about 150 mm., while a third were characterized by small species not exceeding 50 mm. and often less.

Table IX embodies a series of rough estimates of the largest diameters attained by British species of ammonites during the times mentioned, and notes also the hemeræ represented by the ammonite faunas in the Gloucestershire strata described by Mr. Richardson,[1] also those of Hierlatz.

TABLE IX.—SIZE AND DISTRIBUTION OF AMMONITES IN PART OF THE LIAS.

Dates.		Size in millimetres.	Localities. Gloucestershire.	Localities. Hierlatz.
Wessexian				
1.	*Phricodoceras*	428	[×]	
Raasayan				
7.	*leckenbyi*	380		
6.	*aplanatum*	150		
5.	*macdonnellii*	75		
4.	*raricostatoides*	95		
3.	*bispinigerum*	70		×
2 b.	*subplanicosta*	50	×	
2 a.	*densinodus*	110	×	
1 b.	Armatoids	50	×	
1 a.	Echiocerates	50	×	×
Deiran				
8.	*lymense*	165		
7.	*Radstockiceras*	380		
6.	*Gleviceras*	450	×	
5.	*polyophyllum*	135		
4.	*oxynotum*	300	×	
3.	*biferum*	50	[×]	
2.	*simpsoni*	200		×
1.	*Gagaticeras*	50		×
Mercian				
7 c.	*lacunata*	50	×	
7 b.	*subpolita*	50	[×]	×
7 a.	*denotatus*	200	[×]	

Concerning this table, it may be remarked that the figures given are round numbers, and that all species of 50 mm. or less have been entered as 50. The largest species are not necessarily those which give their names to the hemeræ, and some of them are as yet unnamed. That periods of large and small ammonites follow each other like waves (have an undulatory character when plotted) is shown in Table X (p. 95), which also graphically illustrates that during the period mentioned (Mercian 7 to Wessexian 1) there were only these following dates of big or moderately large ammonites, nearly all the rest being times of fairly small forms[2]:—

[1] Those present, but not described by him, are placed in brackets.

[2] [In order to avoid misconception, perhaps it is necessary to point out that the present is only a plotting record of maximum sizes at certain dates: therefore, all contemporary species below the maximum are disregarded. Quite another investigation would be to plot the sizes of all contemporary species (large, medium, and small), and then to illustrate chronological variations in maxima, minima, average, numerical frequency, and so on. But nothing so elaborate has been given here.]

Wessexian	1.	*Phricodoceras.*
Raasayan	7.	*leckenbyi.*
Deiran	8.	*lymense.*
	7.	*Radstockiceras.*
	6.	*Gleviceras.*
	4.	*oxynotum.*

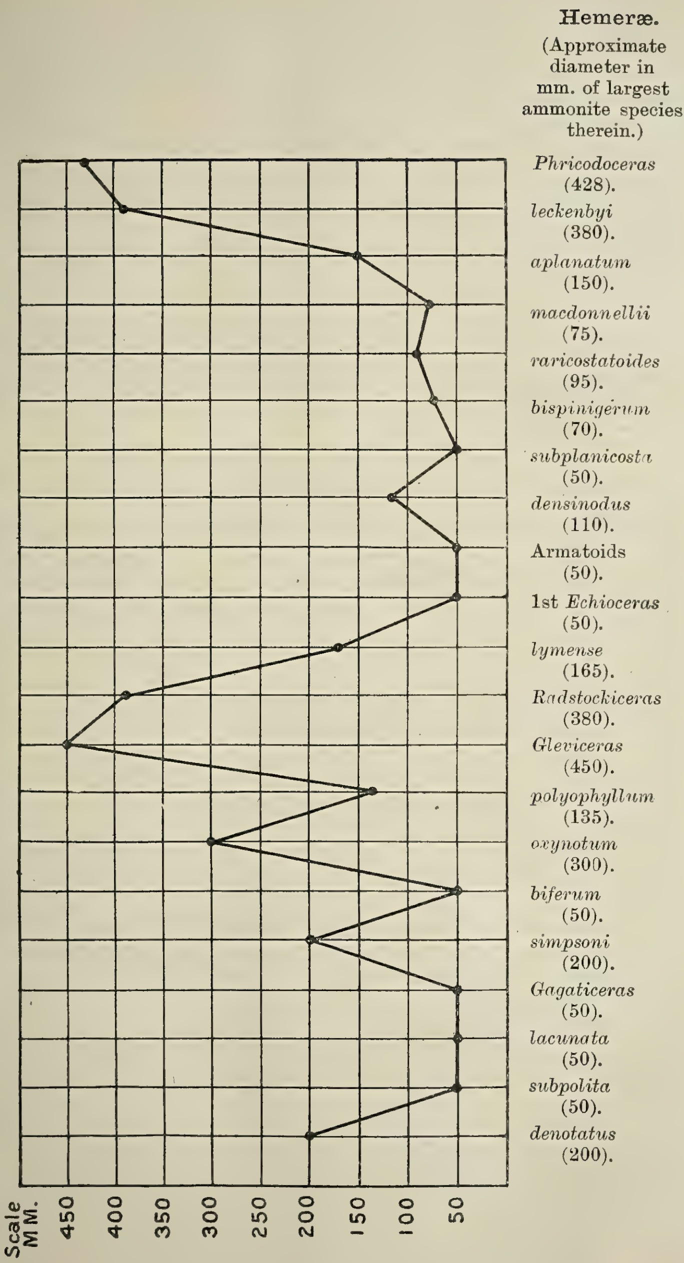
Of these Gloucestershire shows only preserved strata of the two lowest, of which the *Gleviceras* deposits seem from this investigation to fail in places. The other episodes of bigness appear to fail altogether.

The *Oxynoticeras-oxynotum* fauna would not be considered large, because, as already noted, the specimens usually found are truncated—so much so as to be colomorphs sometimes; but it must be reckoned by the living size, and not by the fossil size.

The deductions to be drawn, therefore, seem to be that the strata of Hierlatz and Spezia were not deposited in a landlocked sea unfavourable to ammonites; that no special palæogeographical delineation is required to meet their case; that micromorph ammonites, like those of the *Schlotheimia-lacunata* series, had a wide European extension—Spezia, Hierlatz, Würtemberg, Rhone Basin, Gloucestershire, Yorkshire; that the time when they lived was a time of small ammonites; that in this case, and in others, the deposits of the dates when small ammonites lived happen to have been preserved at Hierlatz and Spezia, while those when large ammonites flourished happen to have been removed: that much the same phenomena are found in Gloucestershire extending over a longer range of time; but that the opposite phenomena—the preservation of strata laid down while large ammonites flourished, and in some cases the loss of strata deposited while small ammonites lived—are found in the contiguous area of North Somerset. Therefore the small size of the ammonite fauna of Hierlatz and Spezia, in so far as they are micromorphs, is a chronological, not a geographical, phenomenon due to diastrophic movements accidentally preserving strata of certain dates; and, in so far as they are colomorphs, the same diastrophic agencies may be the cause—the colomorphs being small, because reduced by geological agency in the course of earth-movements causing redeposition of strata and a breaking-off of the outer whorls of ammonites.

When these studies of Jurassic Chronology are more advanced, it may be possible to present a complete plotted table showing chronologically the rise and fall in size (diameter) of British Jurassic ammonites, which should be of considerable interest; but at present collection-failure and publication-failure in regard to large forms might vitiate the results. In any case, the collection of data is no small task. For instance, only lately have I obtained evidence of a megalomorph in the Upper Kimmeridge Clay—post-*virgula*—in the shape of a fragment of commencement of body-chamber of a *Perisphinctes* of the *rotundus* type as interpreted

Table X.—Illustrating approximate Maximum Diameters of Ammonite Species in a Sequence of Hemeræ (Wessexian 1 to Mercian 7) and their Undulatory Character.



by A. d'Orbigny.[1] This was rescued from a rockery at Headington, near Oxford, and is from the well-known nodule-band. It would have formed part of a specimen some 415 mm. (16 inches) in diameter, and, allowing about another whorl for completion of body-chamber, as one may with such forms, it must when alive have been a giant exceeding 600 mm. (2 feet) in diameter—thus rivalling the megalomorphs of the Portland Stone. And it was a massive form, for the fragment gives 115 mm. ($4\frac{1}{2}$ inches) of whorl-breadth over its strong ribs.[2] Such giants seem to be a new record for the Kimmeridge Series; but the workmen at the brickyard of Long Crendon (Buckinghamshire) had reported that some years ago, in making an excavation deeper than usual—that is, a few feet below Hartwell Clay—they had encountered specimens as large as barrow-wheels, that would be in the position of the same bed. Unfortunately, this brickyard is now closed and dismantled.

IV. Emendations and Corrections of the Earlier Paper.

Certain errors happen to have crept into my former paper,[3] partly misprints, partly misapprehension of information kindly supplied. Some further information has also been published, and other data have been communicated to me, in some cases suggesting certain emendations.

P. 259, line 10. For *three* read *there*.

Table V, facing p. 267; Dorset Coast, Bed 103. For *D*[*eroceras*] aff. *lorioli* read *Microderoceras* aff. *lorioli*.

The presumed generic position of this and allied species is explained in the Palæontological Appendix (pp. 306, 307), written long after the table was prepared; and the lapse of uniformity escaped notice. Dr. W. D. Lang has now shown me, as the result of further work, fragmentary crassicostate *Echioceratа* of *raricostatoides* pattern from the base of Bed 103. The association with *Microderoceras* aff. *lorioli* points presumably to non-sequence and derivation as result of erosion; there is still no evidence and no room for the *aplanatum* and *macdonnellii* faunas (Raasayan 6, 5) on the Dorset Coast.

It may be suggested that it is advisable to separate for recording purposes the *lorioli* fauna and horizon from those of *leckenbyi*. The former occurs at Radstock, according to Mr. J. W. Tutcher, in the 'base of *armatus*' (*leckenbyi*, Raasayan 7), which accords with the Dorset evidence: there it is found distinctly below *leckenbyi* and allies. The following analysis (Table XI) seems to indicate that there may be two horizons, because the geographical ranges do not coincide.

[1] IV, 1, p. 558 & pl. ccxvi, figs. 4–5, pl. ccxxi (*giganteus*).
[2] Author's Coll. No. 2939.
[3] II, 8.

TABLE XI.—FAUNAL ANALYSIS OF RAASAYAN 7.

	West Scotland.	Yorkshire.	Somerset.	Dorset Coast.	Rhone Basin.	Freiburg Alps.	Würtemberg.	Austria Alps.
Raasayan 7 [b]. *leckenbyi* fauna	×	×	×	×	×	...	×	
Raasayan 7 [a]. *lorioli* fauna	..	..	×	×	×	×	...	×

It would seem advisable for the present to record the faunas separately, marking what the Dorset Coast shows to be the upper one (Bed 105) as Raasayan 7 b, and the lower one (Bed 103) as 7 a.

Table V. Bed 94. Dr. Lang tells me that I have misread his information—that *Deroceras bispigínerum* is 25 feet below the top of Bed 99 instead of 15 feet. This brings it into the top of Bed 93. The relative position remains the same; but this places it in close connexion with *subplanicosta* forms, and suggests that the armatoid horizon of Bed 96 ought to be kept separate: it would have to be referred to as 'the second armatoid horizon,' for the present. The numbering and tabular record, p. 276, would be as in the following table:—

TABLE XII.—FAUNAL ANALYSIS OF RAASAYAN 3.

	West Scotland.	Yorkshire.	Dorset Coast.
Raasayan, 3 [b], 2nd armatoid	×	×	×
3 [a], *bispinigerum*	...	...	×

P. 267, line 1. For *rapidly* read *readily.*

P. 276. Table IX, Whitbian 2, *acutum.* Dr. A. E. Trueman states that *Tiltoniceras acutum* and *T. costatum* occur in the upper portion of a 3-foot bed in the Lincoln district with some Dactyloids, but that the latter alone characterize the lower horizon.[1] This corresponds well with already-observed discrepancies in the geographical distribution of *Tiltoniceras* and these early Dactyloids.

In the Northampton district a post-*acutum* bed of sandy clay with no fossils is reckoned as top part of the Transition-Bed.[2] This underlies the Fish- and Insect-Beds, a deposit which, on the evidence yielded by the ammonites, is to be separated from the *tenuicostatum* or *exaratum* horizons.

[1] XXI, 2, pp. 103, 106. [2] XX, 1, p. 34.

P. 276. Table IX, Wessexian 7. A cross should be put under Würtemberg, to indicate the presence of the *bronni* fauna there.

P. 282, line 7. Mr. C. P. Chatwin tells me that he has now found a copy of Mayer-Eymar's paper in the Society's Library, bound up in a series of tracts.

P. 292, footnote 2. *For* 'S. 32' *read* 'S. 16.'

P. 293, footnote 4. *For* pl. xlv *read* pl. xlii.

P. 316, line 11. *For* '360' *read* '260.'

„ line 22. *For* 'XXX' *read* 'XXXI.'

P. 324, line 15. For '*leviceras*' read '*Gleviceras*.'

V. Summary.

In this communication the following points are discussed:—

(1) The ammonite and some brachiopod faunas of the Lias of Gloucestershire and Worcestershire.

(2) A method of faunal plotting as an aid to faunal analysis.

(3) That in the collection, analysis and comparison of faunas, the following causes of failure have to be considered:—Stratal, Depositional, Faunal, Dispersal, Exposure, Collection, Arrangement, Nomenclature, Fossilization, Preservation, Extraction, Zonalization, Publication; but several of these are not applicable to results derived from the investigation of limited areas.

(4) The evidence appears not only to support the conclusions of my former paper, but to show that in certain cases a fuller sequence of faunal episodes may be required.

(5) The fauna of small ammonites in these Liassic beds, especially that of small *Schlotheimiæ* at Gloucester, suggests comparison with the faunas of Hierlatz and Spezia. The use of technical terms for different sizes of organisms, especially for small forms, is briefly illustrated.

(6) It is suggested that the strata and faunas of these Continental localities are not so exceptional as they appear to be at first sight; and that English localities may be studied with advantage, in comparison with and explanation of the features of these Continental deposits.

(7) It is found that the preserved strata of the Gloucestershire–Worcestershire Lias under consideration happen in the main to be deposits of dates when the living ammonites were rather small; while there is faunal failure and presumably stratal failure of the times when large ammonites flourished. The converse phenomena are mainly illustrated by North-Somerset deposits.

(8) The times when large and small ammonites lived appear to follow one another like waves, illustrated even in a short table of Liassic deposits.

(9) As a result of the investigations connected with this paper it seems to be advisable, for recording purposes at any rate, to make the following further subdivisions in the scheme set forth in my former paper:—

TABLE XIII.—REVISED CHRONOLOGY.

Age.	Former paper.	Suggested divisions.
WHITBIAN	7. *subcarinata.*	7 b. *bifrons.*
		7 a. *subcarinata.*
	4. *exaratum.*	4 b. *exaratum.*
		4 a. *murleyi* (Fish-Bed).[1]
	2. *acutum.*	2 b. *acutum.*
		2 a. *athleticum.*
RAASAYAN	7. *leckenbyi.*	7 b. *leckenbyi.*
		7 a. *lorioli.*
	4. *raricostatoides.*	4 c. *raricostatoides.*
		4 b. *tubellum.*
		4 a. *rhodanicum.*
	3. *bispinigerum.*	3 b. 2nd armatoid.
		3 a. *bispinigerum.*
	2. *subplanicosta (densinodum).*	2 b. *subplanicosta.*
		2 a. *obsoletum (densinodum).*
	1. 1st *Echioceras.*	1 b. 1st armatoid.
		1 a. 1st *Echioceras.*
MERCIAN	7. *denotatus.*	7 c. *lacunata.*
		7 b. *subpolita.*
		7 a. *denotatus.*

These subdivisions are not to be regarded as foregone conclusions. They are in some cases theoretical, based mainly on evidence of geographical discrepancies in distribution shown in the paper, and they are put forward with the distinct intention of inciting further research.

And it is not to be concluded that they are final, either as regards the number of divisions or as to the names appended. For instance, Raasayan 4 will probably require still further division: see Table VII, p. 79, of this paper, and see also for additional evidence my 'Palæontological Classification . . . of certain Jurassic Rocks of Skye & Raasay,' Table iii, p. 70 ('The Mesozoic Rocks of Applecross, Raasay, & North-East Skye' Mem. Geol. Surv. Scotland, 1920). A necessary prelude to such further division is a critical examination and adequate illustration of the very numerous series of *Echioccrata*—a task of considerable magnitude. When that is completed, it may be found that other names than those now selected are more suitable for marking the Echiocerate horizons; the same may be the case in regard to other divisional names: too often they have to be used on the principle of 'that or none.'

(10) The analysis of the Gloucestershire Lias described by

[1] The lower part of the *latescens* zone of B. Thompson ('Geology of Northamptonshire' Geol. Assoc. Jubilee vol. 1910, pp. 462, 463), containing carinate serpenticones of *latescens* aspect; but *A. latescens* Simpson is a *Pseudogrammoceras* of Yeovilian 4 (see II, 4, No. 79). Such carinate serpenticones from the Fish-Bed of Alderton–Dumbleton (Gloucestershire) had been named *A. murleyi* by my father (I, p. 90), which I always thought was a *nomen nudum*. But lately, thanks to Mr. J. W. Tutcher's bibliophile ardour, discovery of figure and description has been made in a copy of Moxon (XI, pl. xxiv, fig. 6, and explanation of the plate)—now a scarce work.

Mr. Richardson has produced many points for consideration, but one more may be mentioned. Hitherto the Gloucestershire Lias deposits have been considered as showing a fairly complete and typical sequence. Now it may be seen that, in the middle of what appears to be a quite conformable set of clays of the Middle Lias, there is, between the *subplanicosta* horizon and the *bronni* clays, a great gap in the sequence, during which there was deposited in the Hebrides some 300 to 400 feet of strata and above them another 100 feet or so in Yorkshire. Thus the gap represents some 500 feet of strata, which is about half the thickness, perhaps, of all the Middle and Lower Liassic strata of Gloucestershire. Just the upper part of this gap may be filled by the deposit some 30 feet thick yielding the brachiopoda discussed above, p. 71. Traces of a *Phricodoceras* fauna and the more or less local *tubellum* episode seem to point to the presence of pockets of strata preserved in places; and they suggest the possibility that further research may reveal traces of some of the faunal horizons of this big gap preserved in pockets, or more or less remaniés, in the area of the Severn Valley.

(11) The following Table (XIV) gives my interpretation of the dating of the Gloucestershire–Worcestershire strata discussed.

TABLE XIV.—GLOUCESTERSHIRE–WORCESTERSHIRE LIAS: DATING AND FAUNAL DISTRIBUTION.

Ages.		Strata with Fauna.
HWICCIAN,	5.	*Oistoceras* [*Amblycoceras* sp.] (23), *Lytoceras* (22), *Androgynoceras* (21).
	2.	*Acanthopleuroceras solare, quadratum* (20).
	1.	*Liparoceras cheltiense* (19).
WESSEXIAN,	10.	*Acanthopleuroceras valdani*, etc. (18)
	9.	*Tragophylloceras* spp. (17).
	7.	*Polymorphites* [*Uptonia*] *bronni* (16).
	?.	*Rhynchonella thalia* (15). Gloucestershire, Dorset?, Normandy.
	?.	*Cincta* spp. (14). Gloucestershire, Somerset, Dorset, Normandy, Würtemberg.
	?.	*Rhynchonella* sp. [*rostellata*] (13). Gloucestershire, Würtemberg.
	[1.	*Phricodoceras*.]
RAASAYAN,	4 b.	*Bifericeras tubellum* (12). Dorset, Gloucestershire, Yorkshire.
	2 b.	'*Polymorphites polymorphus*' (11). *Bifericeras subplanicosta* (10).
	2 a.	*Microceras* spp. (9).
	1 b.	*Cymbites globosus* (8). *Deroceras* spp. (7).
	1 a.	*Echioceras* spp. (6).
DEIRAN,	6.	*Oxynoticeras guibalianum* [*Gleviceras*?] (5).
	4.	*Cheltonia* (4), *Oxynoticeras oxynotum* (3) + '*Pol. polymorphus*?'
	[3.	*Bifericeras biferum* group. Warwickshire; Gloucestershire (Aston Cross, near Tewkesbury, and Cheltenham); Somerset (Canard's Grave, near Shepton Mallet); Würtemberg.]
	2?	*Oxynoticeras ferrugineum* [*flavum*] (2).
	1?	*O.* [*Arietites*] *cluniacensis* (1).
MERCIAN,	7 c.	*Lacunata* horizon, *Schlotheimia lacunata* series, *Schl. glevensis* series, *Schl. cheltoniensis*, *Schl. rumpens*. Yorkshire, Cheltenham, Gloucester, Rhone Basin, Würtemberg, Italy.
	[7 b.	*Subpolita* horizon, *Schlotheimia subpolita* series. Yorkshire, Cheltenham, Hierlatz.]
	[7 a.	*Denotatus* horizon. *Arietites denotatus*, etc. Yorkshire, Cheltenham, Würtemberg.]

For the geographical distribution of the faunas of the various dates reference may be made to my former paper[1]; but some supplementary information of this kind is appended in certain special cases. The numbers in parentheses refer to the positions given in Table I of this paper (facing p. 70). Words in brackets followed by such numbers are interpretations of Mr. Richardson's finds; but, without such numbers, they have reference to faunas not mentioned by Mr. Richardson.

(12) The evidence considered in this paper seems to support still further the fragmentary character of the geological record noticed by Dr. J. W. Evans in the discussion on my former paper. His surmise of non-sequences without palæontological evidence is correct: such are known in the Oolites, and will come for notice in the continuation of these studies. Such chronological studies, providing a method of recording not only non-sequences but the maxima of deposit (work performed) in stated times, have, when made with precision, much bearing on the question of the duration of geological time—a subject of general interest.

(13) A palæontological paper should accompany this one; but to attempt it now would mean a very long delay—one out of all proportion to its value. And meanwhile there are more important stratigraphical papers to be attempted: certain preparatory studies for work on the correlation of the Oolites.

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Discussion.

The President (Mr. G. W. Lamplugh) in conveying the thanks of the Fellows to the absent Author, and also to Dr. Lang for reading the paper, remarked that in some cases the size of the fossils in a deposit appeared to have been dependent upon the accident of preservation, the smaller forms having been quickly entombed and protected while the larger forms were partly or wholly destroyed through longer exposure. The accident of preservation was a factor of prime consequence in every discussion of this kind, and, although always readily acknowledged in the abstract, was liable to be overlooked in the concrete.

Dr. W. D. Lang said that, while appreciating the great value of the Author's conclusions to workers in the Lias, he was not convinced of the reality of alternating periods of time characterized respectively by large and by small ammonites. If this were so, we should not find large and small forms in the same bed. For instance, in the Belemnite Stone, very large *Lytocerata* were found; but there also occurred small species of *Beaniceras* which, no doubt, the Author would call phaulomorphs. Further, he was not prepared to go as far as the Author in recognizing non-sequences. To take one instance—the Author, in his previous paper had proposed this sequence of horizons, from below upwards—*latæcosta*,

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CONTENTS.

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ORDINARY MEETINGS OF THE GEOLOGICAL SOCIETY TO BE HELD AT BURLINGTON HOUSE.

SESSION 1920–1921.

1920.		
Wednesday,	December	1 —15*
1921.		
,,	January	5*—19*
,,	February (*Anniversary Meeting*, Friday, February 18th)	2*—23*
,,	March	9 —23*
,,	April	20*
,,	May	4 —25*
,,	June	8 —22*

[*Business will commence at 5.30 p.m. precisely.*]

The asterisks denote the dates on which the Council will meet.

2nd capricorn, 3rd capricorn, *davœi*; and, because the middle two terms were missing in Dorset, he claimed a non-sequence. But, so far as the evidence went, it was equally arguable, and surely far more natural, to suppose, that the 2nd capricorn was contemporaneous with the *latœcosta*-, and the 3rd capricorn with the *davœi*-horizon; and this would do away with the necessity for calling in a non-sequence in Dorset where no evidence for it appeared. Though not prepared always to go so far as the Author, the speaker wished to acknowledge the stimulus of his work, as well as the encouragement and help that he had received personally from the Author.

The SECRETARY read the following contribution to the Discussion sent by Dr. A. E. TRUEMAN:—

'Through the kindness of the Author, I have been allowed to read his paper in manuscript. A valuable feature of this communication is the further application of the methods of faunal analysis. The paper is perhaps most interesting however, because the Author has stated so clearly his ideas on correlation, and has given a fuller explanation of his "law of dissimilar faunas"; the facts now adduced by the Author seem to prove conclusively that dissimilar faunas are very rarely due to different geographical conditions, but usually indicate that the deposits are of different age. It appears to me, however, that certain species may have had a restricted distribution within the British Liassic seas, and, while the Author's methods are of very general application, careful collecting may in some cases yield more accurate results. I ought, however, to point out that, wherever Liassic horizons have recently been studied by detailed collecting, the results have confirmed the conclusions at which the Author had arrived from his faunal analyses.

'The importance of the minute subdivisions that are made possible by this work cannot be overestimated. Quite apart from their biological interest, they are becoming of great value to the economic geologist. The Author showed some years ago the connexion existing between Jurassic anticlines and synclines and hidden coalfields; in a forthcoming paper Prof. Cox and I have endeavoured to trace such Jurassic movements, but we have found that only the thinnest zones can be used for the purpose, and that, generally speaking, there is a great lack of sufficient detail. The requisite evidence can only be obtained by using methods such as the Author has so successfully developed.'

3. *On* Two Preglacial Floras *from* Castle Eden (County Durham) By Mrs. Eleanor Mary Reid, B.Sc., F.L.S., F.G.S. (Read March 24th, 1920.)

[Plates VII–X.]

I. Introduction.

In September 1915,[1] and again in December 1918,[2] Dr. C. T. Trechmann described before this Society Drifts underlying the Boulder-Clay of the Durham coast, at Castle Eden. Some of the Drift is found as the infilling of a number of fissures in the Magnesian Limestone which here forms the bed-rock of the district, the whole being overlain by the Boulder-Clay. The fissures vary in width from 5 to 120 feet, the two with which I am here concerned being described as No. 4 & No. 5: of which the former is 27 feet, and the latter, the widest of all, 120 feet wide. Both are exposed on the foreshore between tide-marks after the scouring of the shore by gales, and are seen to run out seawards in a north-east by east direction, approximately at right angles to the trend of the coast, being lost under the sea.

The infilling of the fissures is of a mixed character, and consists of

'various materials that were transported in front of the earliest ice-sheet that advanced upon this part of the coast; the direction of transport being from the north-east. Besides angular fragments of red sandstone, marl, and Magnesian Limestone......there occur clays of different colours, also masses of peaty wood and trunks of trees, which have been torn up from the present area of the North Sea by the advancing ice-sheet, and thrust as glacial erratics into the fissures.'

Some of the clays contain seeds, and early in 1918 a few of these seeds were sent to me for examination. From time to time, as the state of the foreshore served to obtain it, I received more material.

Most of the seeds are very heavily pyritized, some being entirely preserved in pyrites; and in spite of all the measures that could be taken, many upon drying became distorted and burst, others became covered with efflorescence, while yet others, to my great regret, disintegrated and fell to pieces before I could photograph them.[3] In this way some of the most beautiful specimens were lost, while others became almost unrecognizable.

Including 9 species of mosses, 114 species of plants have been distinguished. No less than 89 species of flowering plants have

[1] 'The Scandinavian Drift of the Durham Coast, etc.' Q. J. G. S. vol. lxxi (1915) pp. 53–82 & pl. viii.

[2] 'On a Deposit of Interglacial Lœss & some Transported Preglacial Freshwater Clays on the Durham Coast' Q. J. G. S. vol. lxxv (1919–20) pp. 173–201, figs.

[3] Under a grant from the Royal Society, which has enabled me to obtain the services of Miss D. Minn, I am now able to carry out this work.

been determined generically, of which number 58 have been traced with a considerable degree of certainty to their nearest living allies.

II. Geology and Botany.

In considering the geological aspects of the investigation, I wish especially to emphasize that the study of Pliocene seeds is now available as an instrument by the use of which it is possible to discriminate mixed strata, and to determine the geological age when this is unknown. The first of these points will, I think, become clear if I describe very shortly the course of this investigation.

In his first letter Dr. Trechmann said, 'The deposit should (I think) correspond with the Cromerian beds.' At the same time Mr. A. S. Kennard, who had examined the mollusca from the same deposit, suggested that the deposits were probably of the age which he assigned to the mollusca, namely Ponder's End (Late Glacial).

A preliminary examination showed that the seeds which I then received could be neither the one nor the other. They were older; for among them were extinct Reuverian species and many exotics. As successive small samples reached me, collected as the state of the foreshore served, this first conclusion was borne out. It was confirmed later by the discovery of the atlas vertebra of an elephant, which was pronounced by Dr. C. W. Andrews to belong neither to *Elephas primigenius* nor *E. antiquus*, but to be in all probability that of *E. meridionalis*.

The samples all showed certain characteristics; all contained extinct and exotic species, notably Chinese and North American species; all contained mosses; and all were heavily pyritized; there were no bones, no shells, and no ostracods. But among them came one small sample containing only a few species, which proved to be different. It showed no exotics; the 11 species found were all British; there was no moss, and the seeds were scarcely pyritized; besides, it contained small fish-bones, indeterminable shells, and ostracods. The sample was sent with the others, without any indication that it differed; but the label read 'Preglacial freshwater clay with shells,' not merely 'Preglacial clay' as did the others.

Upon enquiry whether this sample might have come from the clay from which the mollusca had been described, Dr. Trechmann, after mentioning the intimate manner in which the clays were mixed, wrote:

'The brown clay containing the majority of the seeds is evidently the Teglian material,[1] and is devoid of shells. The material in the small bottle was washed from rather similar clay near to it, but containing (so far as I remember) some shells and ostracods. The mass of the blue clay with shells and ostracods which I presume is newer than the Teglian clay contains none or very few seeds.'

[1] At this time I had given Dr. Trechmann to understand that I believed the seeds to be approximately of Teglian age.

At the end of his letter he added

'The dried seeds in the bottle were certainly, I recollect, derived from the more bluish clay with ostracods.'

Dr. Trechmann's letter confirmed, therefore, the opinion that the recognized difference of floras corresponded to difference of strata.

The 11 British species found in the small sample are all temperate species. There is nothing to indicate a climate differing from that of the present day, unless it be that some are rather undersized.

From the foregoing statements it will be seen that an examination of fossil seeds made it possible to discriminate between strata which were intimately mixed, not only *in situ*, but in the way in which their fossil contents reached me.

The further point that I wish to make is this, that it is now possible to determine the age of Pliocene strata by examination of the contained seeds.

It happened that at the beginning of 1919, while I was still engaged upon the Castle-Eden flora, I received material from Pont-de-Gail, in the department of Cantal. It was sent by M. G. F. Dollfus & M. P. Marty, who together had made an examination of the deposit. The evidence of the mollusca showed that the deposit lay at the base of the Pliocene.[1]

This material, for the first time in the study of Pliocene seeds, supplied the knowledge of a seed-deposit low down in the Pliocene, the age of which was known. Hitherto the only seed-deposits of known age were the Cromerian and the Teglian. Both were Upper Pliocene, the one at the top, the other near the base. The age of the large Reuverian flora was not known. All we knew was that it contained many more exotics and extinct species than the Teglian, and must, therefore, be older. We suggested that it should be placed at the top of the Middle Pliocene; a suggestion I now know to be wrong. It is Lower Pliocene.

While examining the Pont-de-Gail collection[2] I was constantly impressed by its general resemblance to the Reuverian. There was the same large number of exotic and extinct species, the same abundance of species belonging to the Chinese and North American association, and, in this comparatively-small flora of 48 species, three were Reuverian. So striking was the resemblance that I was led to attempt a comparison. The difficulty lay in deciding what data to take, when determinations were necessarily of varying degrees of reliability and value. I decided to consider only those species the determination of which I felt confident was accurate so far as it went, and which had been carried far enough to show something definite as to the present distribution of themselves or their nearest allies. I extended the comparison also to the Teglian, so as to learn, in the event of the Reuverian flora lying between the two, where its probable position would be.

[1] 'Découverte d'un Gisement Fossilifère dans le Cantal' C. R. Acad. Sci. Paris, vol. clxvii (1918) pp. 534–35.

[2] E. M. Reid, 'Recherches sur quelques Graines Pliocènes de Pont-de-Gail (Cantal)' C. R. Soc. Géol. France, No. 6, Séance du 15 Mars, 1920

For the three floras the number of species selected were:—Teglian 100, Reuverian 133, Pont-de-Gail 17. I decided to compare the percentages of the total number of exotics, and of the number of species belonging to the Chinese-North American association. This association consists of plants now inhabiting Japan, China, Indo-China, the Eastern Himalaya, Assam, Burma, Malaya, Australia, and North America, but not living in Western Europe. The result of the comparison showed that of the selected species the Teglian had 40 per cent. of exotics, the Reuverian 88 per cent., and the Pont-de-Gail flora 94 per cent. Of Chinese-North American species the Teglian had 16 per cent., the Reuverian 54 per cent., and the Pont-de-Gail flora 64 per cent. There could be no doubt that the Reuverian was much nearer the Pont-de-Gail flora than the Teglian. The Teglian is the age of the Norwich Crag, the Pont-de-Gail is the base of the Pliocene: it seemed certain, therefore, that the Reuverian must be Lower Pliocene, and probably some way down in it.

This conclusion was subversive of our former ideas as to the rate at which the character of the West-European flora changed throughout the Pliocene. The change was evidently much slower than we had imagined. I thought it possible, therefore, that the Castle-Eden flora might prove to be older than I had believed at first—a little older than the Teglian. I accordingly extended the comparison to the Cromerian and Castle-Eden floras, selecting the species on the same principles as before. The number of Cromerian species selected was 135 and of Castle Eden 58. The

Table showing the Relationships of Five Pliocene Seed-Floras.

I. *Name of Flora.*	II. *Number of species compared.*	III. *Percentage of whole flora compared.*	IV. *Percentage of exotic and extinct species.*	V. *Percentage of Chinese-North-American species.*	VI. *Age, or suggested age of the strata.*
Cromerian ...	135	89	5	0·74	Top of Pliocene.
Teglian	100	75	40	16	Upper Pliocene (Norwich Crag).
Castle Eden ...	58	55	64	31	Middle Pliocene.
Reuverian......	133	46	88	54	Lower Pliocene.
Pont-de-Gail .	17	35	94	64	Base of Pliocene.

result seemed to indicate very clearly a Middle Pliocene age for the Castle-Eden flora.

When I reached this conclusion, I wrote to Dr. C. W. Andrews to ask whether, supposing that the elephant-remains and seeds should belong to the same bed, my determination of the age of the

seeds would clash with his determination of the elephant. In reply, he wrote as follows:—

'The only elephant-remains that I had from Castle Eden consisted of part of an atlas vertebra. This, I was able to convince myself, was not that of *E. primigenius* or *E. antiquus*; in fact, it nearly resembled that of *E. meridionalis*. This determination can, of course, be only approximate. To be sure of the species one must see the molar teeth. It is quite possible that some older form, perhaps ancestral to *E. meridionalis*, may have had a quite similar atlas vertebra. I do not think that *E. meridionalis* itself occurs before the Upper Pliocene; but that need not worry you, as the determination in this case is too uncertain.'

The Pliocene age of the deposit has been confirmed by the report on the insect-remains, which were examined by M. P. Lesne. The remains were found intermingled with the seeds, and are, therefore, strictly contemporaneous. The short preliminary report and list sent by M. Lesne are given at the end of this section, before the full discussion of the floras.

In presence of these facts it seems probable that the clay from which the greater number of the Castle-Eden seeds was obtained belongs to the middle of the Middle Pliocene, and that from which the smaller number was obtained, to the top of the Pliocene, being rather later than the Cromerian, when the climate was very similar to what it is now.

In considering the character of the two floras I will first deal with the older, for it is the more important. As at present known, it consists of 114 species. The number is comparable with those known from the Teglian and Cromerian, from which 142 and 151 species respectively have been distinguished; but a difference in the amounts of material compared must be noted. Whereas for the Teglian and Cromerian investigations quite 2 cwt. of material was washed, for the Castle-Eden investigation (so Dr. Trechmann tells me) not more than 10 lbs. of clay was washed, or about a twentieth of the amount. It is evident, therefore, that at Castle Eden we are dealing with a flora much richer in species than either of the other two. This fact in itself would indicate an earlier age for the deposit, for the farther we go back in Pliocene time the richer does the flora of Western Europe become.

The flora differs in one respect from that of any other Pliocene deposit that I have examined: namely, in the remarkable scarcity of the seeds of water-plants. It is true that the seeds of many aquatic species occur, but they are represented by very few individuals; frequently by not more than one or two. Usually the seeds of such species are quite embarrassing in their profusion, so that one has to clear them away before it is possible to proceed with the examination of the rest.

In the Castle-Eden flora the commonest species is *Potentilla argentea*, essentially a plant of dry gravelly banks; the next commonest is a species of *Erica*, closely allied to *E. vagans*, two species of *Ranunculus*, not aquatic, and an extinct *Melissa*, probably a woodland plant. Other species showing a dry-bank habitat are an *Alliaria*, a gentian allied to *G. cruciata* (a chalk

and limestone species), *Oxalis corniculata*, *Thymus serpyllum*, *Clinopodium Nepeta*, and *Inula Conyza* (also a limestone species).

Trees and shrubs are represented by *Liquidambar*, *Carpinus laxiflora*, *Betula alba*, *Alnus viridis* and *A. glutinosa*, three species of *Cratægus*, three *Rubi*, an *Ilex*, *Rhus*, *Aralia*, *Erica*, *Solanum nigrum*, and two species of *Spiræa*. There are a few woodland plants, and it is noticeable that most of the mosses are arboreal, or show a woodland association.

The assemblage is altogether peculiar, both in the species present and in those absent. The key to its interpretation seems to lie in the numerical lack of water-plants and the predominance of dry-bank species. The former character indicates that the stream which laid down the deposit was too rapid for mud to accumulate in its bed and plants to root themselves, the latter that the banks were steep and dry; the presence of chalk and limestone plants suggests that the valley was probably cut in the Magnesian Limestone of the district. In part, the glen or valley would seem to have been clothed with woodland or coppice, in part with herbaceous plants. By the stream must have grown some of the various species of Cyperaceæ, *Sparganium ramosum*, *Alisma Plantago*, *Ranunculus sceleratus*, and so on; while very occasionally in a pool or backwater a *Potamogeton* or *Hippuris* would find root Or it may be they were carried into the stream by birds.

The picture is that of an upland valley with steep hillsides, open, or clothed with woods. If this interpretation of the facts be right, it points to the existence in Middle Pliocene times, of an elevated tract of land in the present North Sea area, near the Durham coast. The land must have stood at least 400 or 500 feet above the then sea-level for the stream to have had sufficient volume and force to scour its channel, even if it were a short stream and quickly met the sea; but there is no indication among the plants found, of the neighbourhood of the sea, with the possible exception of a nut allied to *Scirpus tabernæmontani*. This probably implies an inland flora, and in that case it follows that the land must have stood proportionately higher. In contrast to this inland aspect of the earlier Pliocene flora, the later flora, represented with but one exception by aquatic species, does show signs of the neighbourhood of the sea, in the abundance of nuts of *Scirpus tabernæmontani*. It must be remembered, however, that, as the material in both cases is transported, the deposits are probably derived from different areas, and need not represent successive stages of the same area, although they may do so.

The second point of interest in the botany has already been touched upon: the presence of so many species belonging to the Chinese-North American association. The existence of such an association was first detected by us in the Teglian flora, but it was not till we had examined the Reuverian that its full significance suggested itself. Since then, as the table (p. 107) shows, it has been found very markedly in the Pont-de-Gail flora, and to a less degree in that of Castle Eden. The most interesting species found

at Castle Eden are a Japanese hornbeam, *Carpinus laxiflora*, three species of *Cratægus* which belong to a North American section of the genus, three species of Chinese and Japanese *Rubi* related to the raspberry, *Pilea pumila*, the stingless nettle of North America (a few specimens of which were also found at Tegelen), an extinct *Melissa* found also in the Reuverian, whose nearest allies inhabit the Himalaya, the mountains of Khasia, and Java; two species of *Rhus*, an *Ilex*, and a gentian, all more nearly related to Chinese and North American species than to European; also an *Aralia*. The meaning of this Chinese-North American alliance was fully dealt with in the Reuverian memoir—the 'Fossil Flora of the Dutch-Prussian Border,' and I need not discuss it here, except to state that the investigation of the Castle-Eden flora has lent strong support to the theories there set forth.

The examination of the mosses was very kindly undertaken by Mr. H. N. Dixon, M.A., F.L.S. The substance of his report, based on the examination of successive samples, is as follows:—

'*Neckera complanata* and *Homalia trichomanoides* are arboreal mosses, the others (*Thuidium ? tamariscenium*, *Eurhynchium swartzii*, and *E. prælongum*) terrestrial. They are all the ordinary mosses that one might meet in a wood or lane-side now, in any lowland part of England. . . . . The association is one which I think certainly would never be found above 500 feet anywhere in Britain at the present day. *A fortiori*, of course, they quite negative any Alpine or Arctic conditions, so far as they are concerned . . . I have examined the further material from Castle Eden . . . . They are practically the same as the former lot examined, and all with the exception of *Amblystegium kochii* show a distinctly woodland association. They might have been washed down by a stream passing through a wood or copse. The *Amblystegium* would be a stream-side or marsh plant. All of them are common or frequent species at the present time in our lowland woods.'

Mr. Dixon's report seems to bear out the suggestion of habitat that I have made above.

III. Insect-remains from Middle Pliocene Clay.

For the study of the insect-remains I was fortunate in being able to obtain the help of the distinguished entomologist, M. P. Lesne, who has sent a preliminary report, of which the following is a translation. A full report will be published by him later.

'I have recognized ten different species, of which nine yield information of value. The list is as follows:—

I. Orthoptera.

1. *Forficula auricularia* L. A living species, indigenous to England.

II. Coleoptera.

2. *Trechus amplicollis præglacialis*, subsp. nov. *T. amplicollis* is now localized in certain mountain-massifs of the European continent.
3. *Pterostichini* (genus extinctum ?).
4. *Argutor strenuus pliocenicus*, subsp. nov. *A. strenuus* is a living species indigenous to England.
5. *Xantholinus linealis* Olivier. A living species, indigenous to England.

6. *Hydræna reidiana*, sp. nov.
7. *Lathridius nodifer* Westwood. A living species, cosmopolitan.
8. *Anobium domesticum* L. A living species, widely spread throughout the Palæarctic regions.
9. *Hadrobregnus ?* (species extincta ?).

III. Hymenoptera.

10. Apidæ (*? Anthidium*, *? Megachile*, *? Chalicodonia*).'

IV. Plants from the Later (Preglacial) Deposit of Castle Eden.

From the small sample labelled 'Freshwater Clay with shells' the following species were obtained :—

Potamogeton trichoides Chamisso (small).
Zannichellia pedunculata Reichenbach (spines few).
Alisma Plantago Linnæus.
Scirpus palustris R. Brown.
S. tabernæmontani Gmelin (small, but plentiful).
Carex riparia Curtis.
Rumex maritimus Linnæus (one badly preserved fruit).
Ranunculus aquatilis Linnæus.
R. sceleratus Linnæus.
Myriophyllum alternifolium De Candolle (very small).
Cirsium arvense var. *setosum* Koch.

All are common British species.

The association is essentially an aquatic one, into which the fruits of *Cirsium arvense* (three in number) have been blown or carried. The presence of *Scirpus tabernæmontani* in some abundance, and the single fruit of *Rumex maritimus*, probably denote the neighbourhood of the sea and somewhat brackish water.

Several of the seeds are small, and it may be that this fact indicates either a climate or habitat which was unsuited to the full development of the species ; otherwise there is nothing to point to a climate differing from that of the present day in the North of England. It seems probable that the deposit should be assigned to the top of the Pliocene, and is either of Cromerian age, or a little later.

V. Plants from the Older (Middle Pliocene) Deposits of Castle Eden.

List of Species.

Neckera complanata (Linnæus) Huebner. In fair quantity.
Homalia trichomanoides (Schreber) Bruch & Schimper. One fragment.
Thuidium tamariscenium (Linnæus) Bruch & Schimper.
Eurhynchium swartzii (Turner) Hobkirk. The predominant moss in several forms.
E. prælongum (Linnæus) Hobkirk. A scrap only.
Amblystegium serpens (Linnæus).
A. kochii Bruch & Schimper. A stem or two.
Brachythecium sp.
Hyloconium triquetrum (Linnæus) Bruch & Schimper. A scrap only.
Sparganium ramosum Hudson.
Potamogeton acutifolius Link.
P. pectinatus Linnæus.
P. natans Linnæus.
P. sp. 4.
P. sp. 5.
Naias minor Allioni.
Alisma Plantago Linnæus.
Cyperus sp. 1.
Cyperus sp. 2.
Scirpus sp. 1 (cf. *tabernæmontani* Gmelin).
Scirpus sp. 2.

Scirpus sp. 3.
Cladium sp.
Carex glauca Scopoli. ?
Carex sp. 2.
C. sp. 3.
C. sp. 4.
C. sp. 5.
C. sp. 6.
C. sp. 7.
C. sp. 8.
C. sp. 9.
Cyperaceæ genus (?) sp. 1.
Do. do. sp. 2.
Do. do. sp. 3.
Do. do. sp. 4.
Carpinus laxiflora Blume.
Betula alba Linnæus.
Alnus glutinosa Gærtner.
A. viridis De Candolle.
Urtica dioica Linnæus, var. ?
Pilea pumila Asa Gray.
Rumex acetosella Linnæus.
Rumex sp. ?
Chenopodium urbicum Linnæus.
Stellaria aquatica Mœnch.
Cerastium sp.
Ranunculus (*Batrachium*) sp.
R. nodiflorus Linnæus.
R. lateriflorus De Candolle, var. ?
R. sceleratus Linnæus ?
R. sceleratus Linnæus, var. ?
R. edenensis, sp. nov.
Alliaria sp.
Chrysosplenium sp.
Liquidambar sp.
Spiræa Ulmaria Linnæus.
S. erectistyla, sp. nov.
Cratægus acuticarpa Reid (=*Cotoneaster acuticarpa* Reid).
C. microcarpa, sp. nov.
C. nodulosa, sp. nov.
Rosaceæ (Pomoideæ) sp. ?
Potentilla argentea Linnæus.
P. pliocenica sp. nov. (=*P.* sp. Bidart, pl. vii, fig. 9).
Rubus lasiostylus Focke.
R. adenophorus Rolfe.
R. cratægifolius Bunge.
Oxalis corniculata Linnæus.
Rhus dunelmensis, sp. nov.
Rhus sp. ?
Ilex oblonga, sp. nov.
Hypericum sp. (=Reuverian sp. 3, pl. xiii, fig. 22).
Viola palustris Linnæus.
V. silvestris Reichenbach.
V. vaginata Maximowicz.
V. sp. (=Tegelen sp., 1907, pl. i, fig. 22).
Hippuris vulgaris Linnæus.
Aralia cordata Thunberg.
Umbelliferæ (Saniculæ) (?) genus (?) sp. 1.
Umbelliferæ (Ammineæ) (?) genus (?) sp. 2.
Umbelliferæ genus (?) sp. 3.
Erica cf. *vagans* Linnæus.
Primulaceæ genus (?) sp.
Gentiana (*Aptera*) sp.
Ajuga decumbens Thunberg.
Sideritis sp.
Prunella vulgaris Linnæus.
Melissa elegans, sp. nov.
Thymus serpyllum Linnæus.
Clinopodium Nepeta O. Kuntze.
Labiatæ (Stachioideæ) genus (?) sp. 7.
Do. do. sp. 8.
Do. do. sp. 9.
(=Reuverian, pl. xvi, figs. 25–27; also Tegelen 1910, fig. 42).
Labiatæ (indeterminable).
Solanum nigrum Linnæus.
Valeriana dioica Linnæus.
Inula Conyza De Candolle.
Pulicaria dysenterica Gærtner.
Carpolithes sp. 1.
C. sp. 2.
C. sp. 3.
C. sp. 4.
C. sp. 5.
C. sp. 6.
C. sp. 7.
C. sp. 8.
C. sp. 9.
C. sp. 10.
C. sp. 11.
C. sp. 11 ?
C. sp. 12.
C. sp. 13.
C. sp. 14.
C. sp. 15.
C. sp. 16.

VI. Description of Species.

TYPHACEÆ.

Sparganium ramosum Hudson. (Pl. VII, fig. 1.)

Two perfect endocarps, agreeing in every way with the fruit of

Sparganium ramosum, were found. One of these, which was highly pyritized, decayed and fell to pieces.

Length = 3·7 mm.; breadth = 2·2 mm.

S. ramosum ranges throughout the Northern Hemisphere.

POTAMOGETONACEÆ.

POTAMOGETON ACUTIFOLIUS Link. (Pl. VII, fig. 2.)

Three specimens belong to this species. The recurved style distinguishes it from *P. trichoides*, in which the style is directed forward.

Length = 2·3 mm.; breadth = 2 mm.

The species occurred in the Pliocene of Tegelen in Holland. It is an inhabitant of the British Isles, though rare, being found only on the eastern side of the country from Aberdeen southwards.

Its present distribution is throughout Europe, the Caucasus, and Australia.

POTAMOGETON PECTINATUS Linnæus. (Pl. VII, fig. 3.)

Four specimens agree in every way with this species.

Length = 3·5 mm.; breadth (before germination) = 2·5 mm.

The species was found both in the Teglian and in the Cromerian. Its present distribution is throughout both northern and southern temperate regions.

POTAMOGETON NATANS Linnæus. (Pl. VII, fig. 4.)

A single nut agrees in every way with the species.

Length = 3 mm.; breadth = 2·7 mm.

This species occurs in the Cromerian. At the present day it is widely distributed throughout the Northern Hemisphere, and occurs also in Australia.

POTAMOGETON sp. 4. (Pl. VII, fig. 5.)

Nut ovate, inflated, with small central depression; ventral margin convex above, concave in the middle, having a downward-directed spine near its base; dorsal margin convex; attachment basi-ventral; style subapical, recurved; keel reaching almost to the style, smooth, convex transversely. One specimen.

Length = 2·8 mm.; breadth = 2 mm.

I am unable to identify this species.

POTAMOGETON sp. 5. (Pl. VII, fig. 6.)

Nut ovate, inflated, central depression very broad and shallow; ventral margin convex above, straight below; dorsal margin convex; attachment basal; style very small, slender, recurved; keel not reaching the style, having a strong median ridge, but depressed so that the edges of the nut form ridged margins; the keel, the ridged margins, and the median ridge together give rise to channels

on either side of the crest; at the base these channels expand, and form two well-marked pits.

Length=3 mm.; breadth=2·1 mm.

There is considerable resemblance in size and general shape between this species and the last, but a close examination shows the distinctive characters of each as described.

I have not been able to identify the species.

From Tegelen, British species only were recorded; from the Reuverian 10 species were described, none of them British. I have a fairly complete collection of British species, but can find nothing to resemble these two. It is probable that they are exotic.

NAIADACEÆ.

NAIAS MINOR Allioni.

A small fragment of the base of a seed was found. It was quite characteristic, showing very clearly the ladder-like sculpture. It was however very small, being smaller than any other specimen of the species that I have seen. Unfortunately, this minute specimen decayed before it was possible to photograph it.

Naias minor, as well as *N. major*, occurred in the greatest abundance in the Teglian and Cromerian. It did not occur in the Reuverian, though several extinct species were recorded. At Castle Eden this minute fragment is the sole representative of the genus. Its present-day distribution is very wide, extending throughout Central Europe, the Mediterranean region, Central Asia, China and Japan, and tropical Africa.

ALISMACEÆ.

ALISMA PLANTAGO Linnæus (var.?). (Pl. VII, fig. 7.)

Achenes narrow, oval, almost oblong; narrow cuneiform in section; style apical.

Length=1·8 mm.; breadth=·75 mm.

These achenes are rather narrow and thick, and have a subapical style. In the living *A. Plantago* the style is usually near the middle of the ventral margin, but occasionally it is as in the fossil. Although the character appears fairly constant in the few nuts found at Castle Eden, for the reason that I have been able to match them from recent specimens, I do not like to separate them as a variety. Tegelen specimens have the same style as those from Castle Eden, but are broader, and resemble more closely the average achenes of the living species. Cromerian specimens have a ventral style.

The present distribution is throughout the northern temperate regions and Australia.

CYPERACEÆ.

CYPERUS sp. 1. (Pl. VII, fig. 8.)

Nut small, broadly oval, triangular in section, truncate at the base, not stipitate; style short; surface showing small hexagonal pits, and beneath these fine, beaded, longitudinal striations.

Length=·7 mm.; breadth=·5 mm.

In 1910 there were figured from Tegelen two species of *Cyperus*. One (*op. cit.* sp. 1, fig. 49) is very close to this Castle-Eden species in size and in the character of its sculpture, but it is a little broader.

Both show one characteristic that is rare in *Cyperus*: they are not stipitate. This marks them as not belonging to any European species. Both at Tegelen and at Castle Eden the nuts were abundant.

CYPERUS sp. 2. (Pl. VII, fig. 9.)

Nut broadly oval, triangular, scarcely truncate at the base, not stipitate; style short; surface shining, showing the remains of large hexagonal pits, and beneath these coarse, beaded, longitudinal striations. Seven specimens.

Length=1·2 mm.; breadth=·75 mm.

This species is distinguishable from the last by its greater size and its bolder striations. Like the last it is not stipitate, and does not belong to any European species. In size and shape it is very similar to *C. pilosus* Vahl, which also is not stipitate, a native of the tropics of the Old World.

SCIRPUS sp. 1 (*cf.* S. TABERNÆMONTANI). (Pl. VII, fig. 10.)

This broken nut in its general shape and cell-structure resembles *S. tabernæmontani*, but it appears to have been narrower and smaller than any specimens of this species that I have seen. It is probably a variety.

Length (incomplete)=2 mm.; breadth (incomplete)=1 mm.

SCIRPUS sp. 2. (Pl. VII, fig. 11.)

Nut regularly oval, plano-convex, not stipitate; style short; finely pitted with cells having a central boss; one nut shows a broad bristle or stamen.

Length=1·5 mm.; breadth=1 mm.

SCIRPUS sp. 3. (Pl. VII, fig. 12.)

Nut oval, flat, rather soft, not stipitate; style very short, surface of quadrate cells with central boss; showing near the base a ring of depressions, which probably corresponds to the position of attachment of the bristles or stamens.

Length=1·3 mm.; breadth=·7 mm.

Cladium sp. (Pl. VII, fig. 13.)

Fruit minute, rhomboidal, stipitate; style short; utricle shining, formed of elongate cells with a central boss; beneath the utricle, can be seen the outline of a small nut occupying the lower two-thirds of the utricle; the nut appears to be rounded above and urceolate below.

Length=1·75 mm.; breadth=·9 mm.

The shape of this fruit and the character of its cells agree with *Cladium mariscus*, but it is much smaller than this species. The apparent size and shape of the nut would agree with minute nuts of *Cladium* found in the Pliocene of Bidart, near Biarritz. No nuts free from the utricle have been found at Castle Eden.

A second abortive fruit containing no nut has also been found.

Carex glauca Scopoli (?). (Pl. VII, fig. 14.)

Nut broadly oval, triangular in section; style short; very coarsely pitted with quadrate cells.

Length=1·5 mm.; breadth=1 mm.

The nut almost certainly belongs to *Carex glauca*, with which its characters agree, but is somewhat distorted.

C. glauca at the present day inhabits Europe, Western America, and Northern Africa.

Carex sp. 2. (Pl. VII, fig. 15.)

Nut ovate, flat, minutely and regularly punctate with cells having a central boss. Two specimens.

Length=2·1 mm.; breadth=1·3 mm.

Carex sp. 3. (Pl. VII, fig. 16.)

Nut plano-convex, elongate oval; style short; very coarsely pitted.

Length=1·9 to 2·1 mm.; breadth=·8 mm.

Carex sp. 4. (Pl. VII, fig. 17.)

Nut regularly oval, flat or plano-convex; striate, and rather coarsely but inconspicuously pitted.

Length=1·3 to 1·4 mm.; breadth=·75 mm.

Carex sp. 5. (Pl. VII, fig. 18.)

Nut narrow oval, sharply triangular in section, stipitate; style long, terete; very coarsely pitted with quadrate cells, the lateral walls of which are grooved on the surface.

Length (including stalk and style)=2·25 mm.; breadth=·7 mm.

Carex sp. 6. (Pl. VII, fig. 19.)

Nut elongate oval, triangular in section, usually much distorted, as though thin-walled; style rather short, conical; very coarsely pitted with quadrate cells.

Length=2 mm.; breadth=1 mm.

CAREX sp. 7. (Pl. VII, fig. 20.)

Nut oval, sharply triangular; style long, curved, triangular at the base, terete above; finely pitted.

Length (including style)=2·2 mm.; breadth=1·1 mm.

CAREX sp. 8. (Pl. VII, fig. 21.)

Nut oval-lanceolate, plano-convex, gradually contracted into the short style, shortly stipitate; surface of oblong cells showing the impression of an outer coat of large cells.

Length=2·1 mm.; breadth=·6 mm.

CAREX sp. 9. (Pl. VII, fig. 22.)

Nut oblong, triangular in section, contracted rather suddenly into the base and short style; closely pitted with cells of moderate size.

Length=2·1 mm.; breadth=·9 mm.?

Five nuts, all much distorted, as though the walls were very thin and soft.

All the nuts of *Carex* are badly preserved. With the exception of *C. glauca* I have been unable to identify any of them as British species.

CYPERACEÆ genus (?) sp. 1. (Pl. VII, figs. 23 *a* & 23 *b*.)

Nut ovate, flattened (by pressure?); style short; outer coat shining, pitted with hexagonal cells; inner coat (free from the outer coat) rough, formed of cells elongate longitudinally.

Length=1·6 mm.; breadth=1·25 mm.

The nut has the shape of many species of *Scirpus*; also the structure of the coats resembles that of certain species, but in no species known to me are the coats separate. The effect may be due to decay.

Since this description was written the nut has disintegrated, and the coats have come apart.

CYPERACEÆ genus (?) sp. 2. (Pl. VII, fig. 24.)

Nuts much distorted and broken, triangular; style short, terete; surface rough, almost tuberculate, of small hexagonal cells with a central boss, and the impressions on them of large quadrate cells belonging to an outer coat.

Length=1·75 mm.; breadth=1 mm.

Although the shape is that of *Carex* nuts, I know of none with so rough a coat as this species has.

CYPERACEÆ genus (?) sp. 3. (Pl. VII, fig. 25.)

Nut oval, plano-convex (or biconvex?), shortly stipitate; style short; surface somewhat rough but glistening, formed of hexagonal cells having a central boss, and bearing the impression of an outer coat formed of elongate cells.

Length=1·7 mm.; breadth=·9 mm.

CYPERACEÆ genus (?) sp. 4. (Pl. VII, fig. 26.)

Nut elongate ovate, flattened, not stipitate, with a narrow flat margin; triangular at the apex, gradually narrowed into a style; there are two coats: the inner rough, horizontally striate, the outer glistening and obscurely thimble-pitted.

Length = 1·4 mm.; breadth = ·5 mm.

CUPULIFERÆ.

CARPINUS LAXIFLORA Blume. (Pl. VII, figs. 27–29.)

Nuts small, ovate, with from three to five low and broad ridges bearing thread-like strands of fibres; area of attachment small; micropyle apical, expanding gradually into the cavity of the nut; walls rather thin, woody.

The nuts are very small. A comparison with the nuts of *C. Betulus* shows that the largest are below the lowest limit of size of this species; nor have they the strong ridges of the species. They are also smaller than any nuts of *C. orientalis*, though they somewhat resemble them in shape. There are a number of very small-seeded Chinese and Japanese species, to some of which they bear a striking resemblance, the species which they most resemble being *C. laxiflora* (Pl. VII, fig. 30), a tree of the Japanese mountains. In this species I have been able to match the fossils, specimen by specimen, from the sheets in the Kew Herbarium. I have therefore referred the fossils to the species.

BETULACEÆ.

BETULA ALBA Linnæus. (Pl. VII, figs. 31 & 32.)

Length (including style) = 1·5 to 2 mm.; breadth = ·5 to ·8 mm.

Seeds of *Betula* occur, although in every case the wings are lost. They most nearly resemble *B. alba*, but are rather narrow. A male catkin belongs to *B. alba*.

B. alba is found throughout Europe, Northern Asia, and North America.

ALNUS GLUTINOSA Gærtner. (Pl. VIII, fig. 1.)

Length = 2·3 mm.; breadth = 2 mm.

Seeds of *Alnus* agree with *A. glutinosa*. Some are very small, and may either be abortive, or belong to another species.

A. glutinosa is an inhabitant of Europe and Northern Asia.

ALNUS VIRIDIS De Candolle. (Pl. VII, fig. 33.)

Seed flat, oval, stipitate, beaked. One specimen only.

Length = 1·8 to 2·5 mm.; breadth = ·8 to 2 mm. (without wing).

This shows at the ragged edges signs that a thin wing has been torn away. The evidence of such a wing, taken in connexion with the size and shape of the seed, marks it as *A. viridis* (Pl. VII, fig. 34).

Alnus viridis is a mountain species ranging throughout Europe, Northern and Eastern Asia, and North America as far south as the Alleghanies. It is not found in the British Isles.

URTICACEÆ.

URTICA DIOICA Linnæus (var. ?). (Pl. VIII, fig. 2.)

Length = ·8 mm.; breadth = ·7 mm.

Several minute nutlets resemble those described from the Cromerian, Teglian, and Reuverian, as *Urtica dioica (?)*, except that they are slightly smaller. The reason of doubt was that the nuts were much smaller, broader in proportion to their length, and nearly oval, not ovate as were all the specimens of *U. dioica* with which we compared them. An examination of material in the Kew Herbarium shows that there is a considerable range of size in the nutlets, both on different specimens and on the same specimen, the terminal nutlets being frequently smaller; but the Castle-Eden specimens are smaller than any nut that I could find on any European specimen and most Asiatic specimens. It was not until I came to two sheets with ripe fruit collected by Dr. J. Anderson from Yunnan that I was able to match the fossils (Pl. VIII, fig. 3). On these two sheets nearly every nut that I could see was within the limits of size of the fossil species.

As these sheets are referred to *U. dioica*, I have assigned the fossils to the same species.

PILEA PUMILA Asa Gray. (Pl. VIII, fig. 6.)

Achenes flat, ovate-acute, sometimes slightly stipitate; attachment basal, asymmetric; style apical; finely and evenly pitted.

Length = 1·7 mm.; breadth = ·9 mm.

This species was first figured in 'The Fossil Flora of Tegelen' (pl. ii, fig. 77) when it was described as *Urtica (?)*. I have now found that it agrees in every way with the achenes of *Pilea pumila*, the 'stingless nettle' of North America, which is found throughout the United States and Canada, from the Great Lakes to Mexico. Achenes from Tegelen (Pl. VIII, fig. 4) and North America (Pl. VIII, fig. 5) are figured here for comparison.

POLYGONACEÆ.

RUMEX ACETOSELLA Linnæus. (Pl. VIII, fig. 7.)

Length = 1·3 mm.; breadth = ·95 mm.

Two fruits of *Rumex*, the dull rough surfaces of which show the remains of a closely-adhering perianth, agree in size and shape with *R. acetosella*. The surface is not sufficiently well preserved to show the venation, but the agreement of the fruits is otherwise so close that they must be referred to the species.

R. acetosella ranges at the present time throughout Europe and Northern Asia.

Rumex sp. (Pl. VIII, fig 8.)

Nut; surface smooth, and finely striate.

Length=2 mm.; breadth=1·25 mm.

The nut is highly pyritized and badly preserved. It does not belong to the last-mentioned species. There is also a large tubercle and a small fragment of a fruiting valve which may belong to the same species. None of these are in a condition such as to admit of determination.

Since this description was written the nut has become thickly covered with efflorescence.

CHENOPODIACEÆ.

Chenopodium urbicum Linnæus.

A minute *Chenopodium* seed, of which the outer coat is preserved, resembles the seeds of *C. urbicum*. It is smaller than the average size of the seeds of that species, though exceptionally they are as small as ·6 mm. in diameter. I think that it should be referred to *C. urbicum*.

Diameter=·7 mm.

Unfortunately, since this description was written the specimen has disintegrated and disappeared.

The species occurs throughout Europe and Northern Asia.

CARYOPHYLLACEÆ.

Stellaria aquatica Mœnch. (Pl. VIII, fig. 9.)

Length=·9 mm.; breadth=·8 mm.

A single seed in excellent preservation agrees in every respect with this species. The species is distributed throughout Europe, Northern and Western Asia, and Northern Africa.

Since this description was written the seed has become covered with efflorescence, and has burst.

Cerastium sp. (?). (Pl. VIII, fig. 10.)

A fragment of testa shows large tuberculate cells with deeply-foliate interlocking sutures, characteristic of Caryophyllaceæ. The tubercles are arranged along concentric curves, and, being elongate in the direction of curvature and closely adjacent, cause the testa to be thrown into a series of concentric tuberculate ridges.

Sculpture of this kind is found in some species of *Cerastium*, the seeds of *C. perfoliatum* bearing a very close resemblance to the fossil fragment. I have not been able to find sculpture of exactly this kind on any other genus of Caryophyllaceæ.

RANUNCULACEÆ.

RANUNCULUS (BATRACHIUM) sp. (Pl. VIII, fig. 11.)

Length=·9 mm.; breadth=·8 mm.

A single half-carpel without the epicarp shows the highly characteristic sculpture of this section of the genus *Ranunculus*, elongate parallel-sided pits giving rise to longitudinal striations, with horizontal wave-like ridges.

The achene differs from any recent species of the section that I have been able to find, in being round not obovate, and in being more inflated; it is also very small, only one or two species being as small.

While working recently at material sent to me from the base of the Pliocene of Pont-de-Gail (Cantal) by M. P. Marty, I found two achenes identical in size and shape with this, but differing in having thicker walls and the sculpture apparently not so coarse and bold. The Pont-de-Gail species is in a better state of preservation and retains the epicarp, so that it is difficult to compare the two; therefore, until more material is obtained from Castle Eden, I cannot say whether they are the same. The Pont-de-Gail species has been described under the name of *R. gailensis*.

RANUNCULUS NODIFLORUS Linnæus. (Pl. VIII, fig. 13.)

Length=1·3 to 1·8 mm.; breadth=1 to 1·2 mm. Average length=1·6 mm.; average breadth=1·2 mm.

A small tuberculate *Ranunculus* occurs at Castle Eden, which resembles a species described from Tegelen as *R.* cf. *humilis*[1] in size, shape, and surface-pitting, but differs in the degree of development of its tubercles. The degree of difference is this. Forms with highly-developed tubercles occur at Tegelen only; non-tuberculate forms occur at Castle Eden only; intermediate forms with low rounded tubercles occur at both places.

I have again examined both the Teglian species and *R. humilis*. The Teglian species is smaller than the recent. Both it and the Castle-Eden species are in much closer agreement with *R. nodiflorus* Linnæus (Pl. VIII, fig. 12), and this species shows the same degree of variation in the character of its tubercles as is seen in the Teglian and Castle-Eden fossils. Both the Castle-Eden and the Teglian fossils should, I think, be referred to this species. It is closely related to *R. humilis*, but has a different range, occurring throughout Central Europe and the Orient.

RANUNCULUS LATERIFLORUS De Candolle, var. (?). (Pl. VIII, fig. 14.)

Length=1·9 to 2·5 mm.; breadth=1·2 to 1·7 mm.

Another tuberculate *Ranunculus* occurs at Castle Eden, which is

[1] 'The Fossil Flora of Tegelen, &c.' 1907, p. 15 & pl. i, fig. 6 (Verhandl. K. Akad. Wetensch. Amsterdam, sect. 2, pt. xiii, No. 6).

related to the Reuverian species described as *R. lateriflorus*[1] in the same way as the Castle-Eden forms of *R. nodiflorus* are to the Teglian. The tubercles are less highly developed, no specimen with very prominent tubercles being found at Castle Eden; otherwise there is agreement.

In *op. supra cit.* p. 92 & pl. vii, fig. 34, we described and figured a *Ranunculus* as *Ranunculus* sp. With the abundant Castle-Eden material before me, I now believe this to be a non-tuberculate specimen of *R. lateriflorus (?)*. Therefore, in the Reuverian all varieties occur. At Castle Eden only forms with low rounded tubercles, or non-tuberculate, are found.

I feel a little doubtful whether both Reuverian and Castle-Eden forms should not be referred to a variety of *R. lateriflorus*, as they are more obovate in shape and the base is more wedge-shaped, but they are nearer to this species than to any other living one that I have seen.

Ranunculus sceleratus Linnæus (?).

Length = ·9 mm.; breadth = ·8 mm.

A minute badly-preserved achene seems to belong to this species. It corresponds in size and shape, and shows in the middle the rounded ridges and longitudinal striations characteristic of the species; but the most characteristic feature, the thickened annular margin of spongy tissue, is wanting. There is the suggestion of the impression of large cells, but without this margin I cannot feel certain of the determination.

Ranunculus sceleratus Linnæus, var. (?). (Pl. VIII, fig. 15.)

Achenes oval, inflated; style very obscure; outer coat dark brown, rather thick, somewhat obscuring the annular margin and the sculpture of the endocarp, shining, finely pitted; inner coat thick and hard, with irregular wavy transverse ridges in the middle; annular margin of spongy tissue narrow, except at the base, where it is broad, giving to the achene an oval shape. Eight carpels.

Length = ·8 mm.; breadth = ·65 mm.

The species does not correspond with European forms of *R. sceleratus*, all of which have discoid flat achenes with an annular margin of even width, also a well-marked style, and a thin outer coat showing very clearly the sculpture of the hard inner coat; but I have found in the Kew Herbarium specimens from North America showing the oval form, the obscure style, and the thick outer coat obscuring the sculpture of the inner coat. I have not, however, been able to find any specimen showing the asymmetric arrangement of the annular margin, broader at the base. In the circumstances, I feel doubtful whether the Castle-Eden species

[1] 'The Pliocene Floras of the Dutch-Prussian Border' 1915, pp. 91–92 & pl. vii, figs. 31–33.

should be regarded as a distinct species, as a variety, or be included in the species.

The specimen described from Tegelen (*op. jam cit.* 1907, fig. 5) is the same as the Castle-Eden form of the species.

Ranunculus edenensis, sp. nov. (Pl. VIII, fig. 16.)

Achænium perparvum, ambitu obovatum, inflatum, pericarpio tenui crasse foveato.

Achenes obovate, inflated, thin-walled; attachment basi-ventral; style subapical; outer coat thin, coarsely thimble-pitted, and finely striate longitudinally; inner coat transversely striate.

Length=·8 mm.; breadth=·75 mm.

This minute achene of *Ranunculus* is very common. The walls are very thin, and in consequence it is always distorted. I have been unable to find any *Ranunculus* at all like it. The achene is very thin-walled for that genus, and I considered whether it might be some species of Urticaceæ; but again I can find nothing at all like it, and, as the character of the walls and of the attachment are in keeping with *Ranunculus*, I have placed it under that genus.

CRUCIFERÆ.

Alliaria sp. (Pl. VIII, fig. 17.)

Seed ovoid, hilum basal; testa finely striate longitudinally, formed of quadrate pits with thickened lateral walls: it is folded into conspicuous longitudinal ribs which anastomose, and coalesce along the line of fission of the seed on one side; germination by fission through the base and apex into symmetrical halves.

Length=1·7 mm.; breadth=1 mm.

Characters in every way similar to these are seen in *A. officinalis*; but the seed is usually much larger than the fossil, the quadrate pits are not thickened laterally, and do not therefore cause longitudinal striations, and the folded ribs are closer and less regular. A fruiting specimen, from an altitude of 8000 feet in Kashmir, has smaller seeds, some of which are nearly as small as the fossil, but broader and more oblong (Pl. VIII, fig. 18): they do not show the fine striations. I have been unable to compare the fossil with seeds of the Japanese species *A. brachycarpa* and *A. wasabi*, and have therefore not described it as a new species.

SAXIFRAGACEÆ.

Chrysosplenium sp. (Pl. VIII, figs. 19 *a* & 19 *b*.)

Seed minute, ovoid, raphe forming an external lateral ridge from base to apex; hilum basal, thin-walled; surface glistening, with sparse minute spines arranged in longitudinal rows.

Length=·75 mm.; breadth=·5 mm.

The shape of this seed, the position and character of the hilum

and raphe, and its glistening surface are in keeping with the seeds of *Chrysosplenium oppositifolium*; but it is larger, and the seeds of that species are covered with glands arranged in longitudinal rows, instead of spines. Hardly any of the numerous species of *Chrysosplenium* are represented by fruiting specimens in the Kew Herbarium: but an examination of such material as I could find showed that the fossil falls within the degree of variation of the size of the genus; that the shape of the seed, the character of the hilum and raphe, and the glistening surface, are generic characters; and that some species are hairy or spiny. Thus, a drawing of the microscopic seed of *C. henryi* shows minute hair-like glands, and *C. echium* has thin, winged, longitudinal ribs crested with spines.

The specimen does not belong to any of the European species; but, in view of the large number of species chiefly inhabiting China, Japan, and North America, which I have been unable to examine, I think it unwise to describe it as a new species.

HAMAMELIDACEÆ.

LIQUIDAMBAR sp. (Pl. VIII, fig. 20.)

A fragment of a compound fruit showing receptacular hollows agrees in its structure with the receptacle of *Liquidambar*. It is too fragmentary to describe, but I do not doubt that it belongs to the genus.

L. orientalis was recorded from the Reuverian. There are four species in the genus: one a native of Asia Minor; one of China and Formosa; one of Atlantic North America and Central America; and the other of Central America.

ROSACEÆ.

SPIRÆA ULMARIA Linnæus. (Pl. VIII, fig. 21.)

Follicle crescentic, flat; style apical; attachment ventral; surface rough, coarsely striate dorsally, and pitted.

Length=2·3 mm.; breadth=1·2 mm.

The follicle is in exact agreement with those of *Spiræa Ulmaria*.

Present distribution: Europe and Northern Asia.

SPIRÆA ERECTISTYLA, sp. nov. (Pl. VIII, fig. 22.)

Folliculus parvus, oblongus, sectione transversa triangularis, margine ventrali rectus; stylus ad latus ventrale apicalis erectus.

Follicle small, oblong, triangular in section, facetted at the straight ventral margin; inner faces smooth; dorsal somewhat rough; style erect, apical, at the ventral margin; attachment basi-ventral; dehiscing by a median suture along the ventral angle through the style and upper part of the dorsal face. Two specimens.

Length=2 mm.; breadth=1·2 mm.

The characters of this species resemble those of many species of *Spiræa*, but except *S. ulmifolia* I have found none in which the style is erect and on the ventral margin; not recurved, and either apical, or on the dorsal margin. Though resembling *S. ulmifolia* in these respects, it is much smaller, the ventral margin is straighter, and the carpel is oblong, not obovate.

The genus *Spiræa* is a very large one, with a great number of species inhabiting China, Japan, and North America.

CRATÆGUS.

Three species of *Cratægus* occur at Castle Eden. Two appear to belong to the American section *Microcarpæ*, which at present is represented by three living species. This section has sub-globose fruits not more than a quarter of an inch long; the nutlets are 2 to 5 in number, obtuse at the apex, and ridged at the back.

The third species should apparently be placed in the section *Pulcherrimæ*, of which the fruits are sub-globose, rarely more than a quarter of an inch long, and the nutlets are grooved at the back.

All the species of the first section are in the Kew Herbarium. The Castle-Eden species belong to none of them. The fruits of the two species of the section *Pulcherrimæ* are not in the Herbarium, but Sargent's description shows that the third Castle-Eden species is not one of these. I have, therefore, given to all three new specific names.

All three of the Castle-Eden species are distinguished by their exceptionally long, apical, prominent styles.

CRATÆGUS ACUTICARPA Reid (=COTONEASTER ACUTICARPA Reid). (Pl. VIII, fig. 23.)

Fruit of five carpels; carpels narrow, elongate, greatest breadth about the middle, ventral margin straight, dorsal margin nearly semicircular; surface granulate; junction of adherent and smooth nude areas at a third of the length from the apex on the ventral margin; style terminal, projecting.

Fruit=3 mm. in diameter.

Endocarp: length=3 mm.; breadth=1·5 mm.

A fruit, showing five carpels united and a portion of the flesh at the base, was preserved in almost solid pyrites. Unfortunately, before it could be photographed, it burst and fell in two. There is also a perfect half-carpel (Pl. VIII. fig. 24); but I am somewhat doubtful whether this should be referred to the species, as the nude area is larger.

The way in which the carpels have remained united, the large area attached to the receptacle, which extends between the carpels, and the terminal projecting style, show that this fruit is a *Cratægus*, not a *Cotoneaster* or *Pyracantha*. I have examined all the species that I could in the Kew Herbarium, of all three genera, and find that only in *Cratægus* are these characters to be seen. All species of *Cotoneaster* and *Pyracantha* have the styles

sunk, not prominent. Except the two sections *Microcarpæ* and *Pulcherrimæ* all fruits of *Cratægus* are large, also a number of them have two or three, not five, stones. The nearest living species that I have been able to find is *C. cordata*; but the style is not so prominent, and the carpel not so symmetrical as the fossil: it tends to be nodular, both on the ventral faces and at the dorsal angles.

The species is the same as that described from the Reuverian as *Cotoneaster acuticarpa*.[1]

CRATÆGUS MICROCARPA, sp. nov. (Pl. VIII, figs. 26–28.)

Carpella quinque, parva, confragosa, lata, supra medium latissima, apice complanata; stylus terminalis, exsertus.

Berry globose; carpels five, broad, broadest above the middle; ventral margin straight, convex or angled at the middle; dorsal surface convex, contracted above at the free area, flattened at the apex; a median rib on the dorsal surface; surface rugose all over; junction of adherent and nude areas marked by a deep depression across the dorsal surface at a fifth of the distance from the apex; on the ventral angle junction of areas half-way or less from the apex; style terminal, projecting.

Endocarp: length = 3 mm.; breadth = 1·6 mm.

Several loose carpels and three united carpels were found.

The species is very near to the American *C. spathulata* Michaux, but this is larger, not so rugose, and the style is shorter and less prominent.

CRATÆGUS NODULOSA, sp. nov. (Pl. VIII, fig. 25.)

Carpella quinque, parva, angusta, infra medium latissima, superficie dorsali ob sulcos altos uno mediano uno transverso apice nodulosa, stylo terminali exserto.

Carpels five, narrow, elongate, broadest below the middle; ventral margin straight or slightly convex; dorsal surface uniformly convex in the adherent area, nearly straight and sub-parallel to the ventral margin in the nude area, flattened at the apex, much contracted in the nude area, where at the apex, on either side of a median depression, are the halves of tubercles, which (when the carpels were united) must have formed a ring of five tubercles round the style; junction of adherent and nude areas at a third of the distance from the apex on the dorsal surface, and three-quarters of the distance from the apex on the ventral margin; style terminal, projecting above the flat-topped carpel.

Carpel: length = 2·6 to 2·8 mm.; breadth = 1·2 mm.

Two perfect carpels and several fragments.

The median dorsal groove would seem to indicate that this should be placed in the section *Pulcherrimæ*.

[1] 'The Pliocene Floras of the Dutch-Prussian Border' 1915, p. 98 & pl. xi, figs. 1–2.

Rosaceæ (Pomoideæ) genus (?) sp. (Pl. VIII, figs. 29 *a*–29 *c*.)

A small three-carpelled (?), syncarpous fruit (or possibly when ripe breaking into cocci), funnel-shaped, coriaceous, rough with irregular longitudinal rugosities; calyx five-toothed, adherent almost to the apex; carpels semiovate, facetted, two-seeded; seeds flattish, rough, attached by the inner edge.

Length = 1 mm.; breadth = ·6 mm.

The fruit broke while it was being examined, and part of it crumbled; but the base and one of the cocci were preserved. The coccus is broken dorsally, and shows two minute seeds, of which one later became loose.

The fruit suggests Rosaceæ of the sub-order Pomoideæ, but I have been unable to identify it.

Potentilla argentea Linnæus. (Pl. VIII, fig. 30.)

Length = ·75 mm.; breadth = ·6 mm.

A great number of minute carpels of *Potentilla* agree in every respect with those of *P. argentea*. At Tegelen a single carpel was found; at Castle Eden it is the most abundant fossil. Both the smooth and rugose types occur.

It inhabits the northern temperate regions of both worlds, its habitat being hedge-banks and dry gravelly places.

Potentilla pliocenica, sp. nov. [= *P.* sp. Bidart, pl. vii, fig. 9.] (Pl. VIII, figs. 31 & 33.)

Carpella ovata sive reniformia, lævia, tenuiter foveata.

Carpels subovate, inflated; dorsal margin rounded, scarcely keeled; ventral margin convex below, concave above; apex hooked, and turned towards the ventral margin; surface-sculpture consisting in very minute regular pits over the whole surface: one specimen shows faintly the elongate, irregular, curved ribs found in most species of *Potentilla*, though by no means in all individuals of these species.

Length = 1·1 mm.; breadth = ·7 mm.

This species is not British. It is identical in every respect with a species described from Bidart near Biarritz,[1] the deposit being correlated by us with the Reuverian (Pl. VIII, figs. 32 & 34).

Both at Bidart and at Castle Eden two forms occur, the hooked form described above, and a rounded form. The sculpture in both these forms, at both places, is the same. Whether it is a species which developed achenes of two shapes, or whether they represent two species both of which occur at Bidart and Castle Eden, I am uncertain, but think the former the more probable explanation, though I do not know any recent species that has two forms of achenes.

[1] Jules Welch, 'Les Vallées Pliocènes avec Lignite de Bidart, &c.' Bull. Soc. Géol. France, sér. 4, vol. xv (1915) pl. vii, fig. 9.

Rubus.

The fossil *Rubi* of Castle Eden are distinguished by their very small size and coarse pitting. All belong to the section *Ideobatus*. At first sight, it might be thought that all are variants of some common species; but a careful study of the fruits of living *Rubi* (which are exceptionally well represented by fruiting specimens in the Kew Herbarium) shows that the endocarps are characteristic and conformable to type, and that the degree of variation exhibited by these fossils is much in excess of that occurring in any living species. The same species does not produce endocarps—some with straight and others with double-curved ventral margins, some long and narrow and others semilunar, some thick and others thin. Such differences are specific. All species are not equally distinct, some are more difficult to distinguish than others; but it happens that the Castle-Eden *Rubi* show three very marked types which are rare among living species. I have, therefore, separated these types, and classified them under the living species which show them and in which alone I have been able to find them. It is possible that, among the distorted specimens, other species should be separated; but these I cannot recognize. All three species are inhabitants of China, though one also inhabits Japan.

Rubus lasiostylus Focke. (Pl. IX, figs. 1 & 3.)

Endocarp narrow oval, sub-terete, thick-walled; ventral margin nearly straight; surface-sculpture of large pits elongate longitudinally, and curved from the style to the attachment.

Length = 2 mm.; breadth = ·8 mm.

Three broken endocarps. One shows the complete length and breadth (though broken), another the breadth and thickness. They agree in nearly every detail with *R. lasiostylus* (Pl. IX, fig. 2). So complete is the agreement that, although broken, they must be referred to the species. It is an inhabitant of Central China.

Rubus adenophorus Rolfe. (Pl. IX, figs. 4 & 5.)

Endocarp ovate, flat (partly by pressure?), thin-walled; ventral margin convex below, concave above, causing the apex to be hooked and turned to the ventral side; dorsal margin semicircular; surface-sculpture consisting in large, deep, irregular pits.

Length = 1·7 mm.; breadth = 1·3 mm.

Endocarps of *Rubi* showing the double curve of the ventral margin seen in these species are very rare. The thin-walled flat endocarp of *R. kuntzeanus* shows it, but the apex is too long and slender to agree with the fossil. *R. adenophorus* Rolfe (Pl. IX, fig. 6) is much nearer both in size and in shape, and in the character of its pitting. It is somewhat more inflated; but, if we take into account the fact that a thin-walled endocarp necessarily flattens and crumples, the agreement is exact.

R. adenophorus inhabits Western Hupeh, a province of China.

RUBUS CRATÆGIFOLIUS Bunge. (Pl. IX, fig. 7.)

Endocarp nearly semilunar, inflated, thick-walled; ventral margin straight, or slightly convex, with a very thick smooth straight rim; dorsal margin semicircular; surface-sculpture of large deep pits.

Length=1·6 mm.; breadth=1 mm.

The straight ventral and rounded dorsal margins, giving a semilunar shape to the endocarp, mark it as a very distinct species. I have only found the combination of characters seen in the fossil in *R. cratægifolius* (Pl. IX, fig. 8), a native of China and Japan. To this species, therefore, I have referred the fossil.

GERANIACEÆ.

OXALIS CORNICULATA Linnæus. (Pl. IX, fig. 9.)

Seed ovate, flat, with nine strong transverse ridges; surface of regular hexagonal cells with a central boss (gland?).

Length=1·4 mm.; breadth=·8 mm.

The seeds of *O. corniculata* and *O. striata* so closely resemble one another that it is difficult to distinguish between the species, though it is possible to do so. The average size of the seeds of *O. corniculata* is greater than of those of *O. striata*, the surface-cells are smaller, and the boss less prominent, wherefore the surface is smoother. *O. corniculata* frequently has nine ridges, *O. striata* eight. In all these respects the Castle-Eden species agrees with *O. corniculata* (Pl. IX, fig. 10). to which species I have referred it. The British species *O. acetosella* has longitudinal, not transverse ribs. *O. corniculata* inhabits the temperate and tropical regions of both hemispheres.

Three specimens. Two of these were quite perfect and most beautifully preserved in solid pyrites. Unfortunately, these decayed and disintegrated before they could be photographed. The third specimen showed only the testa of one side of the seed.

ANACARDIACEÆ.

RHUS DUNELMENSIS, sp. nov. (Pl. IX, fig. 11.)

Endocarpium durum, subreniforme, parum complanatum, confragosum, crasse irregulariter lacunosum.

Endocarp hard, subreniform, somewhat flattened; micropyle apical; attachment basal, represented by a small foramen; surface rough, with large irregular hollows.

Length=1·5 mm.; breadth=1·75 mm.

The endocarp is similar to those of many species of *Rhus*. In the recent species in which hollows occur, they are filled with resin. It is very close to the Chinese species *R. punjabensis* var. *sinica* Rekd. & Wils. (Pl. IX, fig. 12), for the seeds of which I am indebted to the curator of the gardens of La Mortola. In shape

the resemblance is precise; but the Chinese species is larger, also it has no resin-hollows. *Rhus glabra*, a North American species, is of the same size; but it is oval, not subreniform, and has no resin-hollows. *R. laurina*, a Californian plant, perhaps most resembles our fossil in size and in the character of the style; but it is not so broadly indented, and the resin-hollows are not so marked.

RHUS sp. (?)

Fruit horizontal, ovate, compressed, thin-walled, covered with a coarse network of fibres, curving from the sublateral style to the attachment; attachment basal; style sublateral; dehiscing by a lateral suture along the greater arc from the style to the attachment.

Length=1·6 mm.; breadth=2 mm.

The shape suggests *R. cotinoides*; but it is much smaller, and thin-walled. It may be an unripe fruit of this species.

There were two fruits; but I regret to say that the better-preserved of the two, which showed the characters described, was lost.

AQUIFOLIACEÆ.

ILEX OBLONGA, sp. nov. (Pl. IX, fig. 13.)

Semina oblonga, angusta, inflata, ventrice angulata, lineis fibrosis longitudinalibus circa tredecim gracilibus inter se ramosis in costis positis instructa.

Seed oblong, inflated, angled ventrally, convex dorsally; hilum triangular, basi-ventral; about thirteen slender, irregular, longitudinal, anastomosing, strands of fibres, carried on as many obscure ribs, both on the dorsal and on the ventral faces: ventral rib and strand of fibres strong and well-marked.

Length=5·5 mm.; breadth=1·75 mm.

This slender form of seed is not common in the genus *Ilex*, and when it does occur the seeds have usually a median dorsal rib only, and smooth lateral faces. I found but one seed that was an exception. This was in a broken berry lying loose, in a cover containing a number of unnamed species collected by Mr. Wilson in Western Hupeh. I was unable to identify the sheet from which the berry came. The living seed is larger and more pointed than the fossil; but its proportions are similar (length=7·25 mm.; breadth=2·5 mm.), and the number and character of the ribs are the same. It is possible that the fossil is not quite so ripe as the living specimen, or that other specimens of the living species, had they been obtainable, might have been smaller.

In view of the extreme rarity of this form of seed among living species, and the only species which it closely resembles being still unnamed, I have thought it best to give to the fossil a specific name.

The genus *Ilex* has its greatest development in China.

GUTTIFERÆ.

HYPERICUM sp. (=Reuverian sp. 3, pl. xiii, fig. 22). (Pl. IX, fig. 15.)

Seed oblong, sharply contracted at both ends, terete; outer coat of small cells arranged in irregular rows; inner coat (seen at the burst end) of interlocking digitate cells.

Length=1 mm.; breadth=·65 mm.

The surface of the specimen is not well preserved. In shape and size it corresponds closely with the Reuverian species, though this appears rather broader from being crushed flat, whereas the Castle-Eden specimen is inflated. The interlocking digitate cells are identical with those seen in the Reuverian species, and I feel little doubt that the species are the same.

A second specimen also occurs at Castle Eden. It agrees with the last in size and shape; but the surface is better preserved, and the outer coats obscure the characteristic interlocking cells. The outer coat of this species is formed of flat hexagonal cells arranged in longitudinal rows showing pitting underneath.

From the fact that the only two specimens found at Castle Eden are identical in shape and size, even though the surfaces of the two do not appear to correspond, I am inclined to think that they belong to the same species. The combined size and form of this seed are peculiar: I have not been able to match the combination among living species; consequently, the evidence that they offer points to both specimens belonging to the same species and belonging also to the Reuverian species. The discrepancy seen in the characters of the coats of the three is of less importance, for the outer coats of *Hypericum* are thin and, as one or another is removed, in part or wholly, so do the external characters of the seed change.

VIOLACEÆ.

VIOLA PALUSTRIS Linnæus. (Pl. IX, fig. 16.)

Seed obovate, circular in section, closely pitted.

Length=1·8 mm.; breadth=1·75 mm.

A complete seed and several fragments agree in size and shape with the seeds of *V. palustris*, and must be referred to the species.

V. palustris is an inhabitant of the northern temperate regions.

VIOLA SILVESTRIS Reichenbach. (Pl. IX, fig. 17.)

Length=2 mm.; breadth uncertain (broken).

The remains of three germinated large seeds agree in length and curvature with this species. The surface shows shallow pits with thick walls, wherefore the pits appear farther apart than in any other species known to me. The characters are all in complete agreement with *V. silvestris*, and the seeds, though broken, must be referred to it. The species is found throughout Europe and temperate Asia.

VIOLA VAGINATA Maximowicz. (Pl. IX, fig. 18.)

Seed with rather fine close pits; at irregular intervals the surface is raised into obscure swellings, elongate longitudinally, which can scarcely be described as tubercles. Two seeds and some broken fragments.

Length = 1·75 mm.; breadth = 1·1 mm.

In size and shape, character of pitting, and character of these tubercles, the fossil agrees with the Japanese species *V. vaginata* (Pl. IX, fig. 19).

VIOLA sp. (= Tegelen sp., 1907, pl. i, fig. 22). (Pl. IX, fig. 20.)

Length = 1·1 mm.; breadth = ·8 mm.

In 'The Fossil Flora of Tegelen' we described a *Viola* seed showing longitudinal flutings. A specimen from Castle Eden shows the same flutings, but in a more marked degree. The seeds agree in size and shape, and in the character of their cell-structure. The fluting appears to be a specific character, and not the effect of under-development. Under-developed or unripe seeds collapse and crumple; they do not remain inflated and become fluted.

Except these two seeds, I have seen none, either fossil or recent, that show this peculiar character.

HALORRHAGACEÆ.

HIPPURIS VULGARIS Linnæus. (Pl. IX, fig. 21.)

Length = 1·3 mm.; breadth = ·5 mm.

A single specimen agrees in every way with the recent species *H. vulgaris*, a plant which at the present day inhabits the whole Northern Hemisphere and South America.

ARALIACEÆ.

ARALIA CORDATA Thunberg. (Pl. IX, fig. 22.)

Endocarp oval, somewhat flattened; ventral margin slightly convex; dorsal margin convex; style ventral, subapical; attachment basi-ventral; surface rough, with very coarse hexagonal pits elongate transversely, and the remains of a rough, crumpled, outer coat.

Length = 1·6 mm.; breadth = 1 mm.

The general shape and character of the coats of this specimen are those of *Aralia*. The genus is very large, most species inhabiting China. The greater number of these have the ventral margin straight, giving a semilunar form to the carpels. The species which most resembles it is *A. cordata*, in which the ventral margin is convex as in the fossil. The greater number of specimens in the Kew Herbarium have carpels larger than the fossil; but a specimen (Coll. Dr. Savatier) shows fruits with carpels in almost exact agreement as to size and shape, which indicates that the fossil lies within the limits of variation of the species. *A. cordata* is an inhabitant of Japan.

UMBELLIFERÆ.

SANICULÆ (?) genus (?) sp. 1. (Pl. IX, fig. 24.)

Mericarp semicylindrical, narrowed at the apex, stylopod conical, no apparent vittæ; ventral face flat, not grooved; dorsal face with three ridges scarcely apparent above, but becoming somewhat winged and crested or scaly below; surface rugose, with very fine longitudinal striations; in one of the furrows two long hairs arise from the same base, and the broken bases of a few other hairs are to be seen; it appears, therefore, as if the primary ridges had been scaly and the furrows hairy.

Length=1·3 mm.; breadth=·5 mm.

The characters imply that the specimen belongs to the section Saniculæ of the order Umbelliferæ; but I have been unable to identify any genus to which it can be assigned.

AMMINEÆ (?) genus (?) sp. 2. (Pl. IX, fig. 25.)

Mericarp narrow, elongate, inflated (flattened by pressure), contracted to a neck above; five ribs nearly parallel, dorsal ribs thread-like, lateral broader, vittæ doubtful.

Length=2·2 mm.; breadth=·7 mm.

The mericarp, though nearly perfect, is distorted and rather difficult of interpretation. I have been unable to identify it.

UMBELLIFERÆ genus (?) sp. 3. (Pl. IX, figs. 26 & 27.)

Mericarp narrow, elongate, beaked; five ribs, three dorsal nearly parallel, two lateral thick (broken), partly covering the ventral face.

Length=2·2 mm.; breadth (broken)=·8 mm. (?).

Two mericarps, both much broken. I have been unable to identify them.

ERICACEÆ.

ERICA cf. VAGANS Linnæus. (Pl. IX, figs. 28–30.)

Seed globular, stipitate; surface of large flat-bottomed or cup-shaped hexagonal cells, the raised margins of which form a strong reticulation over the surface, or give rise to a honeycomb appearance. Diameter=·5 mm.

In 1910, among the unknown plants from Tegelen, there was figured (fig. 58) a small, globular, strongly-reticulate seed. In 'The Pliocene Floras of the Dutch-Prussian Border' (1915, p. 132) it was suggested that this seed might belong to Gentianaceæ, as certain tropical orders have similar seeds. I have now found an abundance of these seeds at Castle Eden. Some show the reticulate appearance characteristic of the Tegelen specimen, but some are not so much inflated, and appear honeycombed; also some are stipitate. In view of the light shed on the species by this abundant new material, I think that it should be referred to *Erica*, and is near

Erica vagans (Pl. IX, fig. 31). The seeds of this species are globular, stipitate, and reticulate, in the same way as the fossil, some showing coarse reticulations over a smooth surface, others being honeycombed; the difference seems to depend on the degree of inflation of the seeds. Though closely resembling the seeds of *E. vagans*, the fossils are slightly larger, and the reticulations coarser and less numerous. Unfortunately, for lack of living material for comparison, I have been unable to carry the determination farther.

PRIMULACEÆ.

PRIMULACEÆ genus (?) sp. (Pl. IX, figs. 32 & 33.)

Seeds small, nearly circular, convex dorsally, sub-pyramidal ventrally; hilum elongate, ventral; surface rough, with small close cells, and the impression of an outer coat of large loose cells.

Diameter = ·9 mm.

The regular form of this seed, its convex dorsal surface and the sub-pyramidal ventral surface, as well as the character of the testa, point to it as belonging to Primulaceæ, and to some genus which has a globular capsule, few seeds, and these attached to sunken pits in the placenta. Seeds of such genera are pyramidal ventrally; while dorsally they conform to the curvature of the capsule, and are not distorted at the margins by mutual pressure. *Anagallis* and *Glaux* have such capsules and seeds, also *Coris* and *Centunculus*. I have been unable to identify the Castle-Eden species.

GENTIANACEÆ.

GENTIANA (APTERA) sp. (Pl. X, fig. 1.)

Seeds minute, oval, flattened, shining; attachment basal; surface beautifully reticulate, reticulations darker than the seed, and elongate longitudinally.

Length = ·5 mm.; breadth = ·2 mm.

The seeds show the form and character of seeds of *Gentiana* of the section *Aptera*. Though many species resemble them I have been unable to find one that exactly agrees. *G. cruciata* (Pl. X, fig. 2) is much larger, and its reticulations fewer and coarser. *G. olivieri* is of the same size, and has reticulations about as coarse; but they are broader, not elongate as in the fossil. *G. macrophylla* has reticulations exactly agreeing; but the seed is much larger. *G. atkinsoni* has a larger seed and finer reticulations; but these are only a few out of many species. Most had no seeds that I could examine, and I have, therefore, not assigned to the fossils a specific name.

They do not belong to any European species of the section, of which by far the greater number of species are natives of China.

LABIATÆ.

AJUGA DECUMBENS Thunberg. (Pl. X, fig. 3.)

Length=1·8 to 2 mm.; breadth=1·4 to 1·5 mm.

Two perfect nutlets and parts of others belong to the genus *Ajuga*, of which the nutlets, in general character, are very similar in different species. In size the nutlets agree with *A. reptans*; but the venation is much finer and more complicated. An examination of the species in the Kew Herbarium shows venation of the kind in *A. decumbens* (Pl. X, fig. 4), a plant recorded from China, Japan, and the Himalaya. It is only the Japanese specimens that show the fine venation; in those from China and the Himalaya it is coarse, but the Japanese specimens are consistent in this respect.

SIDERITIS sp. (Pl. X, fig. 5.)

Nutlets broadly oval, tumid, with a wedge-shaped base; dorsal face convex; ventral face convex above, angled below; outer coat of irregular cells forming a rough, almost tubercled, surface; inner coat smooth, but pitted with deep square or oblong pits, rather far apart and arranged in longitudinal rows.

Length=1·25 mm.; breadth=·9 mm.

Three nuts. Two show the outer coat; the third, which has the same characters otherwise, is without this coat. Very frequently Labiates lose the outer coat during fossilization.

The shape and other characters resemble those of certain species of *Sideritis*, but I have been unable to identify the species. *Sideritis* is a large genus principally inhabiting the Mediterranean regions and Central Europe, though one species (*S. ciliata*) is found in Japan. Unfortunately, I have been unable to examine this Japanese species.

PRUNELLA VULGARIS Linnæus. (Pl. X, fig. 6.)

Length=1 to 1·4 mm.; breadth=·6 to ·8 mm.

Five nuts of *Prunella* agree in every way with those of the living species *P. vulgaris*, except that they are somewhat small. The smaller nuts of *Prunella* are usually about as large as the largest Castle-Eden specimens; the fossils therefore only just lie within the lower limit of variation, but the agreement is otherwise so exact, that I think they should be referred to the species.

MELISSA ELEGANS, sp. nov. (Pl. X, fig. 7.)

Endocarpium elongato-obovatum, cicatrice basi-ventrali elongato-ovata, extra striis longitudinalibis moniliformibus tenuibus apice rete efficientibus ornatum.

Nutlets elongate-obovate; dorsal face convex, with a shallow elongate median depression; ventral face rounded above, angled below; attachment elongate-ovate, subtriangular, basi-ventral; surface marked by fine longitudinal beaded striations, which towards

the apex form reticulations, and at the apex give a slightly toothed appearance; walls fairly thick.

Length=1·5 mm.; breadth=·75 mm.

A species closely resembling this was described and figured in 'The Pliocene Floras of the Dutch-Prussian Border' (1915, p. 133 & pl. xvi, fig. 24) as a Labiate belonging to an unknown genus. I have now found the genus; it is a *Melissa*. There are only three living species of *Melissa*:—the European species *M. officinalis*, and two others: *M. flava* and *M. parviflora*, both plants of the Himalaya, but the latter also a native of China. Of the three, the Castle-Eden species most resembles the Chinese and Himalayan *M. parviflora* in its coarse rugosities, those of *M. officinalis* being both finer and less prominent. *M. parviflora*, however, is larger, more oblong, not so markedly obovate, and the rugosities are not beaded, nor do they give rise to the same marked striations below and toothing above, but rather to reticulations over the whole surface, which become elongate below. Though differing in these respects, the general form and character of the fossil, and the character of the attachment, show that it belongs to the genus.

The Reuverian species is extremely close to that of Castle Eden, some specimens being in almost exact agreement; but the striations and toothing are rather coarser and more marked than the average of the Castle-Eden specimens. Whether it should be considered as a variety, I am doubtful.

A single specimen of *M. officinalis* was recorded from Tegelen. Thinking that a mistake might have been made, and that this form might be the same as the Castle-Eden species, I re-examined it, but see no reason to doubt that its ascription to *M. officinalis* was correct. It does not show the strongly-beaded rugosities of the Castle-Eden and Reuverian species.

M. parviflora occurs as a mountain plant in Yunnan and Mount Omi in China, where it is found in the forests up to a height of 5500 feet, and in the Himalaya as high as 10,000 feet in Sikkim. It also occurs in Malaya.

THYMUS SERPYLLUM Linnæus. (Pl. X, fig. 10.)

Nut minute, globular. Length=·6 mm.; breadth=·6 mm.

This nutlet undoubtedly belongs to a species of *Thymus*, of which there are a great number of species, with nutlets closely resembling one another, frequently differing only in size. One of the smallest is *T. serpyllum*, with the nutlets of which the fossils agree, although they are smaller than the average size, being only comparable with small specimens. The difference of size is partly due to the fossils having lost their outer coat.

CLINOPODIUM NEPETA O. Kuntze. (Pl. X, fig. 11.)

Nut orbicular, ventral face roundly angled, base bluntly triangular, with deep depressions on each side of the attachment.

Length=·9 mm.; breadth=·8 mm.

The character of the base and the attachment of the nut show

it to be a species of *Clinopodium*. The outer coat is missing, but the impression of its cells can be seen faintly on the hard, pitted, inner coat. In form and character of pitting it agrees with *C. Nepeta*.

This species, though rare in Britain, is found on the Continent. It ranges into Western Asia and the Himalaya. Its habitat is dry banks.

LABIATÆ (STACHIOIDEÆ), genus (?) sp. 7. (Pl. X, fig. 12.)

Nutlets nearly globular, with a triangular pyramidal base, scarcely angled on the ventral face; attachment ovate; outer coat fairly thick, somewhat rough, with well-marked hexagonal pits; inner coat hard, obscurely striate.

Length=1·2 mm·; breadth=·9 mm.

Two nutlets: the shape and the attachment of these nutlets indicate that they belong to the sub-order Stachioideæ of the order Labiatæ.

LABIATÆ (STACHIOIDEÆ), genus (?) sp. 8. (Pl. X, fig. 13.)

Length=1 mm.; breadth=·8 mm.

A nutlet smaller than the last, but resembling them in shape, with smooth surface formed of delicate thin-walled quadrate cells, also appears to belong to this sub-order of Labiatæ. In size and cell-structure it resembles *Cranistome versicolor*, a plant of the Himalaya; but the characteristic base is broken, consequently determination is impossible.

LABIATÆ (STACHIOIDEÆ), genus (?) sp. 9. [=Reuverian, pl. xvi, figs. 25–27; also Tegelen 1910, fig. 42.] (Pl. X, fig. 14.)

Length=1 mm.; breadth=1 mm.

Two nutlets, one broken, belong to the species figured and described from the Reuverian, and previously figured from Tegelen. They have not been identified, but appear to belong to the sub-order Stachioideæ.

LABIATÆ.

Other nutlets apparently belonging to two or three species of Labiatæ are too badly preserved for description or photography.

SOLANACEÆ.

SOLANUM NIGRUM Linnæus. (Pl. X, fig. 15.)

A fragment of the margin of a discoidal seed shows the deep cup-shaped cells with crenulate margins characteristic of so many Solanaceæ. In size, curvature, and the character of the cells it agrees perfectly with the seeds of *Solanum nigrum*, to which species it probably belongs. *S. nigrum* is an inhabitant of the Old World.

VALERIANACEÆ.

VALERIANA DIOICA Linnæus. (Pl. X, fig. 16.)

Fruit small, narrow-obovate, truncate at the base, flat, with thin longitudinal strands of fibres.

Length=2·1 mm.; breadth=·9 mm.

This small fruit is not well-preserved, the ribs being partly torn away, and some of the epicarp also; but its size and shape and the character of the pitting agree in every way with *V. dioica*, a plant of European distribution.

INULA CONYZA De Candolle. (Pl. X, fig. 17.)

Fruits oblong, straight, or somewhat curved, flat (by pressure); ribs numerous; surface-cells oblong in longitudinal rows; collar and base oblique in one specimen, the upward slope being in the direction of the convex side. Two specimens.

Length of one fruit=2·3 mm., breadth=·7 mm.; length of second=1·8 mm., breadth=·6 mm.

These fruits appeared to me to belong to *Inula*; but, being unable to identify them, I asked Prof. James Small, who has done much work on the Compositæ, if he would be kind enough to examine them. He identified both as *Inula Conyza*. He reports that the larger agrees in every way with the species in regard to the characters mentioned, the oblique crown being frequently met with in *I. Conyza*; the smaller specimen differs somewhat in its cell-structure from most specimens of *I. Conyza*, but agrees with those from La Mortola, the difference being perhaps due to the warmer and drier climate.

PULICARIA DYSENTERICA Gærtner. (Pl. X, fig. 18.)

Fruit small, narrow, oblong, with eleven or twelve strong ribs; surface-cells flat, oblong.

Length=1·1 mm.; breadth (crushed)=·4 mm.

The fruit has been flattened by pressure, but otherwise agrees in every way with the fruits of *P. dysenterica*, which is a European species.

Since it was described the specimen has broken up.

INCERTÆ SEDIS.

CARPOLITHES sp. 1. (Pl. X, figs. 19 *a* & 19 *b*.)

Endocarp ovate, inflated, fairly thick-walled, finely striate with longitudinal tuberculate striations.

Length=1·4 mm.; breadth=·6 mm.

Two half-endocarps. These appear to be the halves of the same endocarp, though now they do not fit; but this is probably the effect of distortion.

CARPOLITHES sp. 2.

Length=4·7 mm.; breadth (incomplete)=2·5 mm.

A fragment of a large thick-walled endocarp, the surface of which is much decayed, but shows granulation; two longitudinal bands of fibres can be seen, one in the middle, and the other at the margin.

A pyritized fragment from which the testa has decayed shows two cylindrical cotyledons, with an apical depression from which the gemmule has been lost. It agrees in size with the endocarp, and may perhaps belong to it.

Since description both these specimens have disintegrated and crumbled away.

CARPOLITHES sp. 3. (Pl. X, fig. 20.)

A small, cylindrical object quinquelobate at the flat base, the lobes ending above in a ring of five dome-like prominences.

Diameter=2 mm.; depth=2 mm.

The specimen may be a placenta.

CARPOLITHES sp. 4. (Pl. X, fig. 21.)

Two minute adherent seeds or nuts, ovoid, cylindrical, rough.

Length=·55 mm.; breadth=·55 mm.

CARPOLITHES sp. 5. (Pl. X, figs. 22 *a* & 22 *b*.)

Half a seed or endocarp, obovate, inflated, thick-walled; the micropyle appears to have been terminal, and the attachment basal.

Length=3 mm.; breadth=1·75 mm.

CARPOLITHES sp. 6. (Pl. X, fig. 23.)

Height=1·2 mm.; diameter=1 mm.

A small, nearly globose object seated on a disc, or a broken cupule, apiculate, having a large basal foramen. At the edge of the cupule on one side there appears to be a small lateral stalk. I am quite at a loss to understand the relation between the basal foramen and the lateral stalk. The form of this specimen suggests a fruit with an adherent calyx; but I cannot interpret the structure.

CARPOLITHES sp. 7. (Pl. X, fig. 24.)

Seed irregularly cylindrical, surface gnarled and nodular, testa black and shining; hilum apparently basal, but difficult to make out.

Length=1·5 mm.; diameter=1 mm.

I can make no suggestion as to the affinities of this seed.

CARPOLITHES sp. 8. (Pl. X, figs. 25 *a* & 25 *b*.)

Seed (?) ovate-pointed, biconvex, thin-walled; attachment basal, marked by a cup-shaped lipped projection, arillate (?); germinating by a special valve (missing) which seems to have been round, the edges of the valvular opening are involute; a

germination fissure, or perhaps part of the valve, is continued along the margin of the seed through and beyond the apex; surface of thick-walled hexagonal cells.

Length=1·3 mm.; breadth=·8 mm.

Two specimens. The curious structure of these specimens seems best explained as that of arillate seeds. I can suggest no position for them.

Carpolithes sp. 9. (Pl. X, fig. 26.)

Carpel minute, hard, rhomboidal, somewhat winged, beaked, spurred behind, ridged dorsally and ventrally; stipitate, attachment ventral; micropyle apical, gaping; apparently two-seeded.

Length=3 mm.; breadth=·8 mm.; depth (exclusive of stalk) =·5 mm.

If this carpel had been larger, I should have thought that it might be that of *Liriodendron*; but it is so small that I cannot think that any species could have so minute a carpel, though the seeds, and portion of a very small fruiting catkin, were recorded from Reuver. The length of the Reuverian carpel, which had no wing, was 4·5 mm., whereas the Castle-Eden carpel (including the long beak) measures only 3 mm.

I modelled the carpel to a large scale, in order the better to see what kind of fruit it suggested. The curious facetting of the upper and lower surfaces seems to indicate that it formed part of a loose catkin, and that the stalk was sunk in some kind of elongate rhachis.

Carpolithes sp. 10. (Pl. X, fig. 27.)

Achene arcuate, flat; attachment basal, triangular; style apical.

Length=3 mm.; breadth=1 mm.

This appears to have been one of a number of achenes closely adpressed in a whorl. I can suggest no position for it.

Carpolithes sp. 11. (Pl. X, fig. 28; also figs. 29 *a* & 29 *b* ?)

Cupule or placenta truncate-obconical, with a cup-shaped hollow above, and the base deeply hollowed below like another inverted cup; walls somewhat loose-textured, of large quadrate cells; surface light brown, showing the remains of an outer thin, close-textured, black coat, finely striate longitudinally: there are also the remains of what appears to be another light-brown crumpled coat external to these, formed of smooth shining hexagonal cells; but whether this is proper to the cup, or only adherent, I am not certain. The base (the 'inverted cup') shows a well-defined rounded break or 'lip' in its side, by which evidently the peduncle entered, being partly clasped by the cup; it also shows a central boss of fibres at the actual point of attachment. There is no indication of these fibres emerging in the cupule, unless it be at the margin.

Diameter=3·4 mm.; depth=2·4 mm.

The nut belonging to this cupule or placenta probably showed

a differentiated area over which it was attached to the cupule, and corresponding in size to the area of the cupule.

The fragment of a nut (figs. 29 *a* & 29 *b*) showing such an area occurs at Castle Eden. The size of the nut (which is broken) would appear to correspond to that of the cupule. I cannot say, however, whether they belong together, as I have identified neither.

The nut is broken, part of the base only being preserved, but it shows the characters now described. Probable diameter=4·4 mm.; probable diameter of differentiated area of attachment=2·4 mm. The base appears to have been cup-shaped; nut dehiscing by a circumsciss fissure, the graduated thickness of the walls of which indicate that it carried the fibro-vascular bundle; fissure parallel to the boundary of the differentiated area; outer surface of the nut black above, brown in the area of attachment; the surface-cells of this area are quadrate, and correspond in size and character with those seen in the cupule.

It seems probable that the cupule and nut belong together.

CARPOLITHES sp. 12. (Pl. X, fig. 30.)

Capsule very small, campanulate, with numerous (nine or twelve?) minute, subulate teeth; not stipitate; striate.

Length=1·1 mm.; breadth=·6 mm.

CARPOLITHES sp. 13. (Pl. X, fig. 31.)

Capsule campanulate, with five rounded-triangular teeth about a third the length of the capsule.

Length=1·3 mm.; breadth=1 mm.

CARPOLITHES sp. 14. (Pl. X, fig. 32.)

The tapering base or apex of a small fruit cut transversely shows four or five locules. The apex is strongly ribbed, showing six or seven ribs which lower down become less marked.

CARPOLITHES sp. 15. (Pl. X, figs. 33 *a* & 33 *b*.)

A large thick-walled woody carpel, bluntly angled dorsally; attachment ventral; micropyle apical; internally the carpel shows a complicated arrangement of flanges, which are doubtless intended to secure that the fruit shall spring widely open for semination. The arrangement somewhat suggests that of genera of Rutaceæ, but I have been unable to find any to correspond with it.

Length=2·5 mm.; breadth=1·3 mm.

CARPOLITHES sp. 16. (Pl. X, fig. 34.)

A minute, flat, oval seed with a large gaping aperture at the apex (?); surface rough, with irregular longitudinal ridges and transverse wavy lines.

Length=·75 mm.; breadth=·5 mm.

EXPLANATION OF PLATES VII–X.[1]

Plate VII.

Fig. 1. *Sparganium ramosum*, endocarp. 6 : 1.
2. *Potamogeton acutifolius*, endocarp. 6 : 1.
3. *Potamogeton pectinatus*, endocarp. 6 : 1.
4. *Potamogeton natans*, endocarp. 6 : 1.
5. *Potamogeton* sp. 4, endocarp. 6 : 1.
6. *Potamogeton* sp. 5, endocarp. 6 : 1.
7. *Alisma Plantago*, var. ?, carpel. 12 : 1.
8. *Cyperus* sp. 1, nut. 12 : 1.
9. *Cyperus* sp. 2, nut. 12 : 1.
10. *Scirpus* sp. 1 (cf. *S. tabernæmontani*), broken nut. 12 : 1.
11. *Scirpus* sp. 2, nut. 12 : 1.
12. *Scirpus* sp. 3, nut. 12 : 1.
13. *Cladium* sp., nut in utricle. 12 : 1.
14. *Carex glauca ?*, nut. 12 : 1.
15. *Carex* sp. 2, nut. 12 : 1.
16. *Carex* sp. 3, nut. 12 : 1.
17. *Carex* sp. 4, nut. 12 : 1.
18. *Carex* sp. 5, nut. 12 : 1.
19. *Carex* sp. 6, nut. 12 : 1.
20. *Carex* sp. 7, nut. 12 : 1.
21. *Carex* sp. 8, nut. 12 : 1.
22. *Carex* sp. 9, nut. 12 : 1.
23. Cyperaceæ, genus (?) sp. 1 : *a*, outer ; *b*, inner coat of nut. 12 : 1.
24. Cyperaceæ, genus (?) sp. 2, nut. 12 : 1.
25. Cyperaceæ, genus (?) sp. 3, nut. 12 : 1.
26. Cyperaceæ, genus (?) sp. 4, nut. 12 : 1.

Figs. 27–29. *Carpinus laxiflora*, nuts showing variation of size. 6 : 1.
Fig. 30. *Carpinus laxiflora*, small nut. 6 : 1. Japan.
31. *Betula alba*, male catkin. 6 : 1.
32. *Betula alba*, seed (wing torn off). 12 : 1.
33. *Alnus viridis*, seed (wing torn off). 6 : 1.
34. *Alnus viridis*, seed (wing torn off). 6 : 1. Recent.

Plate VIII.

Fig. 1. *Alnus glutinosa*, seed. 6 : 1.
2. *Urtica dioica*, achene. 12 : 1.
3. *Urtica dioica*, achene. 12 : 1. Recent, Yunnan.
4. *Pilea pumila*, achene. 12 : 1. Tegelen.
5. *Pilea pumila*, achene. 12 : 1. Recent, North America.
6. *Pilea pumila*, achene. 12 : 1.
7. *Rumex acetosella*, fruit. 12 : 1.
8. *Rumex* sp., nut. 12 : 1.
9. *Stellaria aquatica*, seed. 12 : 1.
10. *Cerastium* sp., fragment of seed. 12 : 1.
11. *Ranunculus* (*Batrachium*) sp., achene. 12 : 1.
12. *Ranunculus nodiflorus*, achene. 12 : 1. Recent.
13. *Ranunculus nodiflorus*, achene. 12 : 1.
14. *Ranunculus lateriflorus ?*, achene. 12 : 1.
15. *Ranunculus sceleratus* var. ?, achene. 12 : 1.
16. *Ranunculus edenensis*, sp. nov., achene. 12 : 1.
17. *Alliaria* sp., seed. 12 : 1.
18. *Alliaria officinalis*, seed (small specimen). 12 : 1. Kashmir.

Figs. 19 *a* & 19 *b*. *Chrysosplenium* sp., seed : *a*, outside ; *b*, inside. 24 : 1.

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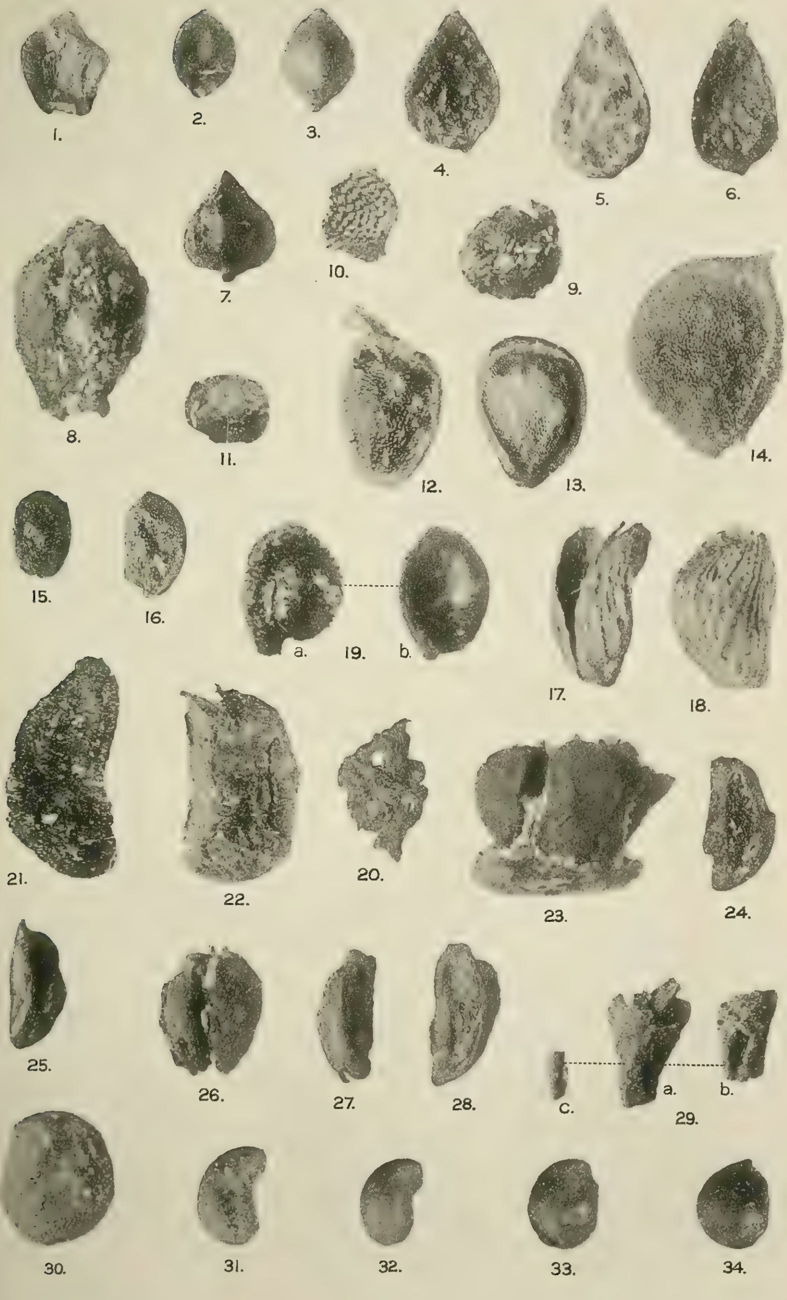
[1] Except where otherwise stated, the specimens are from Castle Eden.

E. M. Reid & D. Minn, Photo.

Bemrose, Collo., Derby.

CASTLE EDEN PLIOCENE.



E. M Reid & D. Minn, Photo.

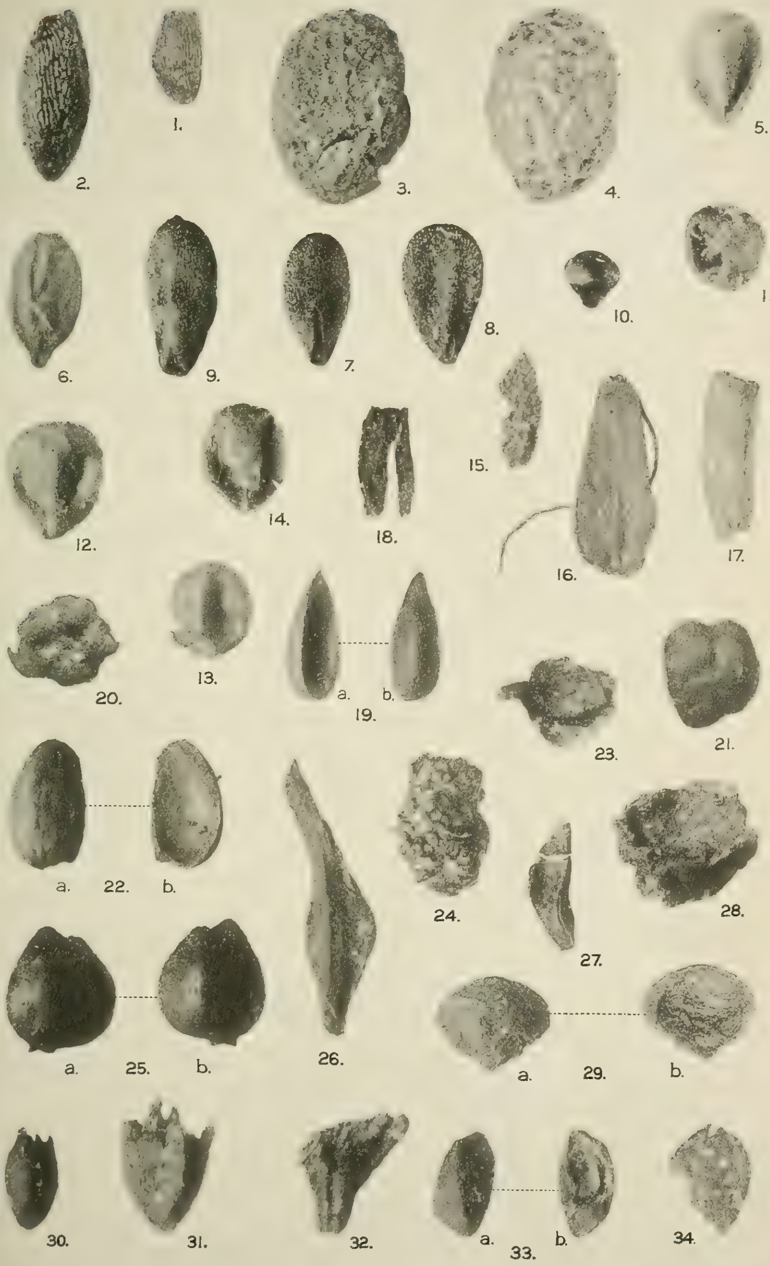
Bemrose, Collo., Derby.

CASTLE EDEN PLIOCENE.

E. M. Reid & D. Minn, Photo.

Bemrose, Collo., Derby.

CASTLE EDEN PLIOCENE.



E. M. Reid & D. Minn, Photo.
Bemrose, Collo., Derby.

CASTLE EDEN PLIOCENE.

Fig. 20. *Liquidambar* sp., fragment of fruit. 6 : 1.
21. *Spiræa Ulmaria*, carpel. 12 : 1.
22. *Spiræa erectistyla*, carpel. 12 : 1.
23. *Cratægus acuticarpa*, three carpels embedded in remains of receptacle. 6 : 1.
24. *Cratægus acuticarpa ?*, carpel, inside. 6 : 1.
25. *Cratægus nodulosa*, carpel. 6 : 1.
26. *Cratægus microcarpa*, two carpels united by remains of receptacle. 6 : 1.
Figs. 27 & 28. *Cratægus microcarpa*, carpels : fig. 27, outside ; fig. 28, inside. 6 : 1.
29 *a*–29 *c*. Rosaceæ (Pomoideæ), genus (?) sp. : *a*, base of receptacle ; *b*, detached coccus ; *c*, seed from the same. 12 : 1.
Fig. 30. *Potentilla argentea*, seed. 24 : 1.
Figs. 31 & 33. *Potentilla pliocenica*, seeds of two forms. 12 : 1.
32 & 34. *Potentilla pliocenica*, seeds of two forms. 12 : 1. Bidart.

PLATE IX.

Figs. 1 & 3. *Rubus lasiostylus*, endocarps. 12 : 1.
Fig. 2. *Rubus lasiostylus*, endocarp. 12 : 1. Recent, China.
Figs. 4 & 5. *Rubus adenophorus*, endocarps. 12 : 1.
Fig. 6. *Rubus adenophorus*, endocarp. 12 : 1. Recent, Hupeh (China).
7. *Rubus cratægifolius*, endocarp. 12 : 1.
8. *Rubus cratægifolius*, endocarp. 12 : 1. Recent.
9. *Oxalis corniculata*, seed. 12 : 1.
10. *Oxalis corniculata*, seed. 12 : 1. Recent.
11. *Rhus dunelmensis*, sp. nov., endocarp. 12 : 1.
12. *Rhus punjabensis*, var. *sinica*, endocarp. 12 : 1. La Mortola.
13. *Ilex oblongum*, sp. nov., endocarp. 6 : 1.
14. *Ilex* sp., endocarp. 6 : 1. Recent, China.
15. *Hypericum* sp., seed. 24 : 1.
16. *Viola palustris*, seed. 12 : 1.
17. *Viola sylvestris*, seed. 12 : 1.
18. *Viola vaginata*, seed. 12 : 1.
19. *Viola vaginata*, seed. 12 : 1. Recent, Japan.
20. *Viola* sp., seed. 12 : 1.
21. *Hippuris vulgaris*, fruit. 12 : 1.
22. *Aralia cordata*, carpel. 12 : 1.
23. *Aralia cordata*, carpel. 12 : 1. Recent.
24. Umbelliferæ (Saniculæ), genus (?) sp. 1, mericarp, dorsal. 12 : 1.
25. Umbelliferæ (Ammineæ), genus (?) sp. 2, mericarp, ventral. 12 : 1.
Figs. 26 & 27. Umbelliferæ, genus (?) sp. 3, mericarps : fig. 26, dorsal ; fig. 27, ventral. 12 : 1.
28–30. *Erica* cf. *vagans*, seeds showing variation of size and sculpture. 24 : 1.
Fig. 31. *Erica vagans*, seed. 24 : 1. Recent, Cornwall.
Figs. 32 & 33. Primulaceæ, genus (?) sp., seeds : fig. 32, dorsal aspect ; fig. 33, ventral. 12 : 1.

PLATE X.

Fig. 1. *Gentiana* (*Aptera*) sp., seed. 24 : 1.
2. *Gentiana cruciata*, seed. 24 : 1. Recent.
3. *Ajuga decumbens*, nutlet, dorsal. 12 : 1.
4. *Ajuga decumbens*, nutlet, dorsal. 12 : 1. Recent.
5. *Sideritis* sp., nutlet, ventral. 12 : 1.
6. *Prunella vulgaris*, nutlet, ventral. 12 : 1.
7. *Melissa elegans*, nutlet, ventral. 12 : 1.
8. *Melissa elegans*, nutlet, ventral. 12 : 1. Reuver.

Fig. 9. *Melissa parviflora*, nutlet, ventral. 12 : 1. Recent, Himalaya.
10. *Thymus serpyllum*, nutlet, basi-ventral. 12 : 1.
11. *Clinopodium Nepeta*, nutlet, ventral. 12 : 1.
12. Labiatæ (Stachioideæ), genus (?) sp. 7, nutlet, ventral. 12 : 1.
13. Labiatæ (Stachioideæ), genus (?) sp. 8, nutlet, ventral. 12 : 1.
14. Labiatæ (Stachioideæ), genus (?) sp. 9, nutlet, ventral. 12 : 1.
15. *Solanum nigrum*, fragment of seed. 12 : 1.
16. *Valeriana dioica*, fruit. 12 : 1.
17. *Inula Conyza*, fruit. 12 : 1.
18. *Pulicaria dysenterica*, fruit. 12 : 1.
Figs. 19 *a* & 19 *b*. *Carpolithes* sp. 1 : *a*, inside ; *b*, outside. 12 : 1.
Fig. 20. *Carpolithes* sp. 3, apex. 6 : 1.
21. *Carpolithes* sp. 4, two nutlets (?) adhering. 24 : 1.
Figs. 22 *a* & 22 *b*. *Carpolithes* sp. 5, endocarp (?) : *a*, outside ; *b*, inside. 6 : 1.
Fig. 23. *Carpolithes* sp. 6, side (cupule below, nut above). 12 : 1.
24. *Carpolithes* sp. 7, side. 12 : 1.
Figs. 25 *a* & 25 *b*. *Carpolithes* sp. 8, the two sides. 12 : 1.
Fig. 26. *Carpolithes* sp. 9, fruit, dorsal. 12 : 1.
27. *Carpolithes* sp. 10, carpel, side. 6 : 1.
28. *Carpolithes* sp. 11, cupule. 6 : 1.
Figs. 29 *a* & 29 *b*. *Carpolithes* sp. 11, (?) broken nut : *a*, outside ; *b*, inside. 6 : 1.
Fig. 30. *Carpolithes* sp. 12, capsule, 12 : 1.
31. *Carpolithes* sp. 13, capsule. 12 : 1.
32. *Carpolithes* sp. 14, part of small fruit. 12 : 1.
Figs. 33 *a* & 33 *b*. *Carpolithes* sp. 15, carpel : *a*, outside, *b* ; inside. 6 : 1.
Fig. 34. *Carpolithes* sp. 16, seed. 24 : 1.

4. *A* Comparative Review *of* Pliocene Floras, Based *on the* Study *of* Fossil Seeds.

By Mrs. Eleanor Mary Reid, B.Sc., F.L.S., F.G.S. (Read March 24th, 1920.)

I. Introductory.

The work on which the following paper is based has been rendered possible only by the help received from many botanists. If it were not for a considerable private collection of seeds and fruits, mounted for microscopic examination, it would have been impracticable, either to gain the knowledge requisite for carrying out the work, or to make the preliminary determinations, which are necessary before it is possible to use the great collections of our public herbaria.

The formation of this collection of seeds, though initially, and essentially, due to my late husband's careful and unwearying labour, has for some years passed the bounds when the work of any single collector could meet the demands of the study of fossil seeds. Help has, however, been received from all sides: by gifts of specimens from Kew (both the Gardens and the Herbarium), the British Museum, the Herbarium of the Muséum d'Histoire Naturelle, Paris, and the Gardens of La Mortola; also by contributions from botanical friends, among whom I would especially mention Mr. James Groves, Mr. C. E. Salmon, Mr. T. A. Dymes, M. Émile Gadeceau, M. J. Simon, and Dr. Tokotaru Ito.

As well as for contributions to my collection, I would also thank the officers of Kew and the British Museum, for their unfailing kindness in helping while I have been at work in the respective Herbaria, and in lending specimens for photography and study.

Of late my work has been greatly furthered, particularly the photographic part of it, by the assistance of Miss D. Minn (of Newnham College, Cambridge), for whose services I am deeply indebted to the Government Grant Committee of the Royal Society.

I especially wish to thank my friends Prof. A. C. Seward, F.R.S., and Mr. James Groves, F.L.S., for allowing me always to apply to them when I have wanted advice or help, and for their great kindness in reading through my manuscripts.

II. History of the Investigation.

The study of Pliocene seeds, carried on by my husband and myself between the years 1904 and 1915,[1] led us to formulate

[1] 'The Preglacial Flora of Britain' Journ. Linn. Soc., Bot. vol. xxxviii (1908) pp. 206–27 & pls. xi–xv; 'The Fossil Flora of Tegelen-sur-Meuse, &c.' Verhandl. K. Akad. Wetensch. Amsterdam, pt. xiii. No. 6 (1907) pp. 3–26 & pls. i–iii; 'La Détermination de l'Âge des Argiles à Briques de Tegelen, Reuver, Ryckevorsel, & Raevels' Bull. Soc. Belge de Géol. vol. xxi (1907) pp. 583–90; 'A Further Investigation of the Pliocene Flora of Tegelen'

certain theories, by which to account for the facts discovered during the course of our investigations. The facts were these: that the Pliocene Epoch had witnessed the existence and extinction in Western Europe, of a flora closely allied to the living floras of the Far East of Asia, and of North America; and, that in whatever part of the Northern Hemisphere the nearest living relations of these exotics, or of any Pliocene exotics, were now found, provided that they were found in lower latitudes, they were nearly always mountain-plants.

The explanation that we gave of these facts shows that the two are related.

To account for the first we extended the theory put forward by Asa Gray [1] to explain the relationship between the living floras of Japan and North America—that they were two divergent streams of migrants from some Polar source.

In the Pleistocene Flora of Western Europe we recognized a third stream.[2] All three were driven south by the ever-increasing cold of the Pliocene. For the East Asian and North American streams the way to the Tropics was open, and they escaped. For the West Asian and European stream, from the Atlantic seaboard till the coastal plain of China was reached, the way was everywhere closed in temperate regions, by impassable East-and-West barriers of mountains, seas, and, perhaps, deserts. Against these barriers successive waves of migrants were driven, and perished. so that by the end of the Pliocene (Cromerian) scarcely a trace of their former existence was to be found, save in their fossil remains.

Had this been all, we might expect to find some part at least of the living elements of the exotic flora established on the plains of North America and China wherever the climate was suitable; but this is not the case. Nearly always the survivors are mountain-plants.[3]

K. Akad. Wetensch. Amsterdam, Verslag. Afd. Natuurk. pt. xix (1910) pp. 262–71, pl.; 'Les Vallées Pliocènes avec Lignite de Bidart, Cénitz & Chabiague (Basses-Pyrénées)' Bull. Soc. Géol. France, sér. 4, vol. xv (1915) pp. 403–27 & pl. vii; and 'The Pliocene Floras of the Dutch-Prussian Border' Med. Rijksopsporing van Delfstoffen, No. 6, 1915.

[1] 'Diagnostic Characters of New Species of Phænogamous Plants, collected in Japan . . . . . With Observations upon the Relations of the Japanese Flora to that of North America & of other parts of the Northern Temperate Zone' Mem. Amer. Acad. Arts & Sci. n. s. vol. vi (1859) pp. 377–449.

[2] 'The Pliocene Floras of the Dutch-Prussian Border' pp. 15–26.

[3] If the theory is true, that successive waves of migrants have found refuge throughout Later Tertiary time in the countries of the Chinese-North American plant-association, it follows that these countries must now exhibit a rich and varied flora representing many Tertiary survivals. Having this view in mind, I was much interested to receive at the end of last year (1919) a letter from Dr. A. Kryshtofovich, informing me that M. V. Komarov had also been led to regard the mountains of Western China as an 'asylum' for plant-life. This conclusion was reached, so Dr. Kryshtofovich tells me, by the study of certain typical Chinese genera, and he adds that M. Komarov's papers were published in the 'Acta Horti Petropolitani.'

To explain this second fact, it is necessary to consider the climatic conditions which succeeded the cooling of the Northern Hemisphere throughout Pliocene time. These were the somewhat rapid transitions of climate from cold to warmth—how many it does not here concern us—which followed in the succeeding Pleistocene Epoch.

During a cold period, the warmest flora to survive in any given district must have been that inhabiting the plains or valley-bottoms. As the climate ameliorated, the plains would become too hot for this flora, and, in order to escape destruction by heat, as it had formerly escaped destruction by cold, it must migrate. In a country of great plains, if the changes of climate were rapid, movement to other latitudes might be too slow to counteract the change of climate; but in a mountain country, comparatively small vertical movements would afford the necessary change. Hence, in a warm period following upon a cold—our present condition—we should expect to meet the migrants, when inhabiting more southern lands than those in which their fossil relations occur, not on the plains (where mostly they had been exterminated), but upon the mountains.

The Lower Pliocene flora of Western Europe is now found most commonly at a height of from 1500 to 2000 metres in the Himalaya and in the mountains of Western China.

Such briefly are the theories put forward in 'The Pliocene Floras of the Dutch-Prussian Border,' in order to account for the facts that I have mentioned. The knowledge of these facts was obtained chiefly from the study of three floras, the Cromerian, Teglian, and Reuverian.

In these three floras we recognized three stages in the chain of events suggested above. The age of the two earlier stages was known from the evidence afforded by mollusca or mammalia; the Cromerian lay at the top of the Pliocene; the Teglian near the base of the Upper Pliocene, being the equivalent of the Norwich Crag. The age of the large Reuverian flora was not known, but it contained many more exotic and extinct species, and many more belonging to the Chinese-North American association, than the Teglian, and must therefore be older than it. We hazarded a guess as to its probable age, and suggested that it might represent the top of the Middle Pliocene, a suggestion I now know to be wrong. It should be placed in the Lower Pliocene.

About two years after the research had reached this stage, I

Unfortunately he does not give the reference. Dr. Daydon Jackson and Mr. S. A. Skan have very kindly looked up the matter for me, and have found two papers written in Russian, but with Latin as well as Russian titles, which appear to be those to which Dr. Kryshtofovich refers. The references to these are as follows:—Vladimir Leontjivic Komarov, 'Prolegomena ad Floras Chinæ necnon Mongoliæ' Fasc. 1 (1908) pp. 1–176, pls. i–iv & 2 maps; Fasc. 2 (1909) pp. 179–388, pls. v–xx & text-figs., Acta Horti Petr. xxix. [I have since heard that these are the papers.]

received two more Pliocene seed-collections for study. The one, derived from material ploughed by the advancing Scandinavian ice-sheet from some part of the area now covered by the North Sea, and thrust as a glacial erratic into fissures of the Magnesian Limestone at Castle Eden, on the Durham coast; and the other from Pont-de-Gail in Cantal.[1]

The Pont-de-Gail deposit has proved of the utmost importance in the study of Pliocene seeds, for its age is known. MM. G. F. Dollfus and P. Marty state, from a study of the mollusca, that it lies at the base of the Pliocene.[2] For the first time this deposit has given knowledge of a seed flora of definite age, low down in the Pliocene.

As at present known, it is a small flora, consisting of but 48 species; but, while working at it, I was continually impressed by its resemblance to the Reuverian flora. There was the same large proportion of extinct and exotic species, of species belonging to the Chinese-North American association, and of mountain-plants; and, of the forty-eight species, three were Reuverian. So striking was the relationship that I felt certain that the two floras must be very nearly of the same age, and was led to try to compare them.

It was difficult to decide, where determinations were necessarily of varying degrees of reliability, and gave varying degrees of information, exactly what species, or forms, to select for the purpose. I decided to consider those only which I felt had been determined with a considerable degree of accuracy, and which I thought might be placed in one of three categories: first, living species now inhabiting the countries where the fossils are found; secondly, exotic species belonging to the association which I have termed 'the Chinese-North American association': that is, species which are found in the countries of the Far East of Asia from Japan to Malaya and Australia, including China, the Himalaya, and Assam, or in North America, but do not now range into Europe; thirdly, exotic species of known genus which do not belong to this association.

I tried to keep a balanced judgment, but some parts of the work were more fresh in mind than others, also it was difficult to know always what to take and what to leave. There were species about which I was undecided; for though they were undoubtedly exotic, sometimes the present range was not known. By excluding them altogether the true proportion of the exotic element would be distinctly under-estimated. It seemed best to include them and classify them merely as exotics, if the genus showed a considerable European and Mediterranean distribution, and there was no definite evidence to place them in the Chinese-North American category. I am aware that this procedure is open to criticism, but I tried not to force the evidence in any direction. The object

[1] E. M. Reid, 'Recherches sur quelques Graines Pliocènes de Pont-de-Gail (Cantal)' C. R. Soc. Géol. France, No. 6, Séance du 15 Mars, 1920.

[2] 'Découverte d'un Gisement Fossilifère dans le Cantal' C. R. Acad. Sci. Paris, vol. clxvii (1918) p. 534.

of the comparison was merely to find out, if possible, how these floras were related. If, in the end, the work led to results which were not even thought of when the selection was made, I hope that it may be considered that the balance has been kept true. It can hardly be chance that these results have been reached. It certainly is not design. I could not have arrived at them had I tried to do so; I should not have known how: the process would have been too complicated.

III. The Comparison of the Floras.

The lists at the end of this paper give the selected species and their allocation to the two categories of exotic species when they belong to these; the species of the Chinese-North American association being marked with one asterisk *, other exotics with two **.

It will appear in the course of the paper that the Chinese-North American species mark an outgoing flora, the living West European species and the other exotics, an incoming flora; and that these two floras were derived from different sources, the one from a Polar, the other from some other source.

The first comparison of the Reuverian with the Pont-de-Gail and Teglian showed conclusively, that the Reuverian was much nearer in age to the Pont-de-Gail flora than to the Teglian, and that its position must be low down in the Lower Pliocene, not, as we had suggested, at the top of the Middle Pliocene.

This conclusion indicated that the change in the character of the flora of Western Europe, north of the east-and-west mountain-ranges, throughout the Pliocene Epoch, was much more gradual than we had surmised; and I was led to reconsider my first estimate of the probable age of the Castle-Eden flora, which it was suggested, in a preliminary report, might be a little older than the Teglian.

With the object of testing this new view, and of discovering the way in which the West European flora changed throughout

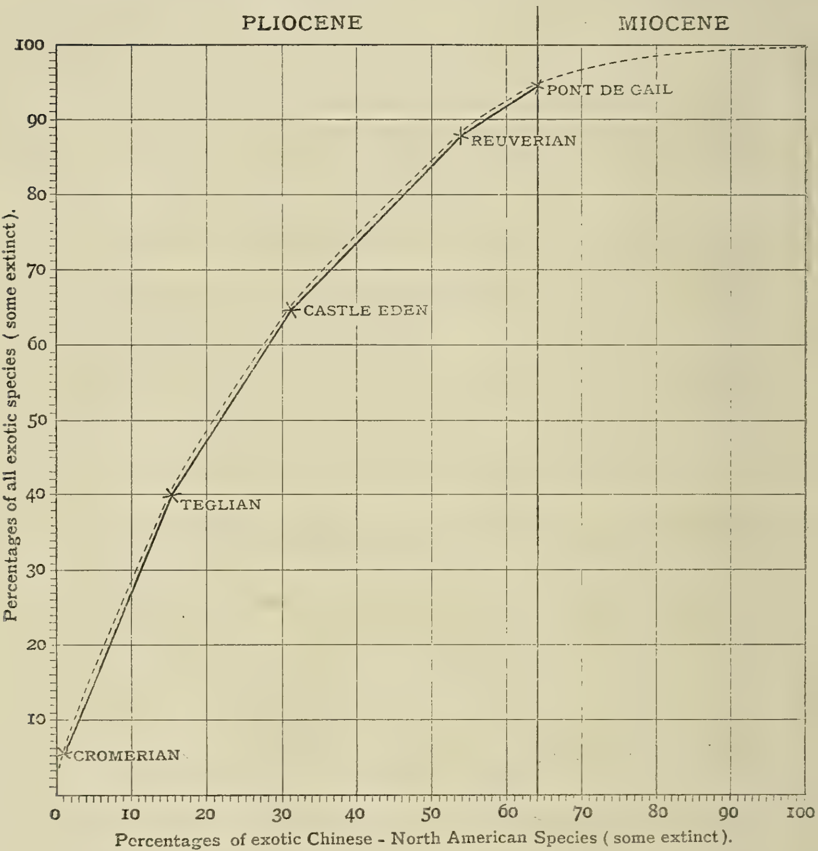
Table showing the Relationships of Five Pliocene Seed-Floras.

I.	II.	III.	IV.	V.	VI.
Name of flora.	*Number of species compared.*	*Percentage of whole flora compared.*	*Percentage of exotic and extinct species.*	*Percentage of Chinese-North-American species.*	*Age, or suggested age of the strata.*
Cromerian	135	89	5	0·74	Top of Pliocene.
Teglian	100	75	40	16	Upper Pliocene (Norwich Crag).
Castle Eden ...	58	55	64	31	Middle Pliocene.
Reuverian	133	46	88	54	Lower Pliocene.
Pont-de-Gail...	17	35	94	64	Base of Pliocene.

the Pliocene, the five principal Pliocene seed-floras were then compared on the basis indicated above.

The table of results is given on p. 149; but I wish at this point to make it clear that the species were selected for comparison purely on the grounds stated above. I had no idea, except in a general

Fig. 1.—*Comparative rates of extinction of Chinese-North American species and flora as a whole, in Western Europe.*



way, what the outcome of the comparison would be. In my mind, I had placed the floras in the relative positions which they were found to occupy; but that was all. Whether a critical examination would bear out the impression gained as to their ages, it was impossible to judge.

Except that the table showed a general accord with my ideas as to the relative positions of the floras, it was a little disappointing.

Columns IV & V looked irregular, and I wondered whether much reliance could be placed on my studies. To test the degree of reliability, therefore, columns IV & V were plotted as a curve. To my great amazement all the five *loci* lay along a regular curve—the curve which shows the relation between the total exotic element and the Chinese-North American part of it, throughout the Pliocene and part of the Miocene (fig. 1).

Before entering upon a discussion of the curve, and the deductions to be made therefrom, it must be stated that it is not an absolute curve conveying an absolute truth, but a personal one of which the truth is limited by the limitation of my knowledge of the seeds of living plants, and by my judgment of the fossil species. Inasmuch, however, as this personal bias holds throughout the entire course of the investigation, it does not, I think, invalidate the general conclusions, although it does perhaps modify them slightly, in this way:—it will be noticed that (see Table, p. 149), accordingly as the age of the deposit increases, the percentage of selected (known) species decreases. The probability, almost the certainty, is, that the unknown species are exotic, and that a large proportion of them belong to the Chinese-North American association. Seeing, however, that it is impossible to prove this, I have had to exclude them. If they could have been included, the percentage of both elements (total exotics and Chinese-North American exotics) in the table would have been increased; and the increase would have been proportionately greater going back in time. This would not necessarily mean any change in the form of the curve, but that each *locus* would be situate a little farther back, and that the division between Pliocene and Miocene would also be thrown farther back: that is, the proportion of the curve representing the Pliocene would be increased, that representing the Miocene would be decreased. Such a change would imply that floras of unknown age, in the Pliocene, would occupy a position a little farther back in time than at present appears, and in the Miocene, a little farther forward.

Be this slight modification as it may, it may be conceded that it is legitimate to draw certain deductions from the curve.

(1) In the first place, I think that it may be claimed that the study of both living and fossil seeds is capable of leading to reliable specific determinations.

(2) That the curve being based purely upon the study of fossil seeds without reference either to palæozoology or stratigraphy, it shows that the results arrived at by this study are in accord with those achieved by the sister studies. Thus, granting that the *loci* of the Pont-de-Gail and Cromerian floras represent fixed periods in time, namely the beginning and ending of the Pliocene, then the position of the Teglian *locus*—that is, its position in time—is in very accurate agreement with that indicated by the palæozoological study of the associated mammals—towards the base of the Upper Pliocene. Moreover, as will appear later, the indication given by the curve, that the extermination of the Chinese-North American element in the West European flora began in the Miocene, is also in accord with the results arrived at by stratigraphy and palæozoology. Consequently it may be claimed, that the study of fossil seeds is able to furnish an instrument of equal delicacy and accuracy

with palæozoology and stratigraphy, for the determination of the age of strata the geological position of which is unknown.

As a corollary, it follows that the positions indicated for the two floras of unknown age—the Castle Eden and the Reuverian—are very approximately correct. The Castle-Eden flora may be regarded as belonging to the middle of the Middle Pliocene; the Reuverian as coming low down in the Lower Pliocene.

(3) By carrying the curve beyond the Pliocene into the Miocene, to the point marked by the co-ordinates of 100—which point, it may be noted, lies very approximately on the curve—it will be seen, that at a period some way back in the Miocene, probably about the middle, or a little earlier, the whole of the flora of Western Europe, north of the east-and-west mountain-ranges, was of the Chinese-North American type. If, as I have suggested, the division between Pliocene and Miocene should lie farther back on the curve, it would indicate that this period lies rather later—not much later—in the Miocene.

I would here remark that the curve depends upon the recognition of the Chinese-North American element in the West European Pliocene flora, but is quite independent of any theory as to why this flora is found here, or what led to its extermination.

Recognizing this, it is noteworthy that the *locus* of 100 on the two co-ordinates indicates that the extermination of the Chinese-North American element began, or perhaps it may be more correct to say, the period at which it was both exterminated, and supplanted by other elements, began at exactly the period which stratigraphy and palæozoology indicate as that at which the elevation of the mountain-ranges, extending from Morocco to Indo-China,[1] attained its maximum. But it was precisely to the presence of these mountain-ranges that we chiefly attributed the extermination of the Chinese-North American flora in Western Europe.[2] Consequently, the curve bears the strongest confirmatory and independent testimony to the truth of our theory of extermination, of which I have given a digest at the beginning of this paper.

(4) In the form of the curve two facts are stated by implication only: these are, the rate of change of the exotic element in the Pliocene flora of Western Europe, other than the Chinese-North American element; and the rate of increase of that part of the flora which survived to form part of the living flora of Western Europe. It is to be noted that, whereas the Chinese-North American element is outgoing, both these elements are incoming, and that they only began to affect the flora of Western Europe during the Miocene Epoch. The questions at once arise—What are they? Whence did they come? I am not prepared to answer these questions, although there are points to which it is well to draw attention, as offering a possible, and perhaps a probable, solution.

Our analysis of the Pliocene Floras (*op. jam cit.* pp. 27–50), further corroborated by the study of the Castle-Eden and Pont-de-Gail floras, shows that, of the Pliocene species which at present form part of the West European flora, those with a circumpolar distribution are, in by far the majority of cases, marsh- or water-plants; land-plants have, save exceptionally, a more limited distribution; most have a range extending in varying degrees from the Himalaya throughout the Near East, the Caucasus, Central Europe, and the Mediterranean region; a few also range into China and Japan.[3] A very similar distribution of aquatic and land-plants is seen among the incoming exotic species; which points to the indigenous and exotic elements having a common origin.

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[1] A. de Lapparent, 'Traité de Géologie' 4th ed. vol. iii (1900) pp. 1513, 1777, 1807.

[2] 'The Pliocene Floras of the Dutch-Prussian Border' 1915, pp. 18, 19.

[3] It is possible that some of these may be derived from late waves of Polar migrants.

The circumpolar distribution of aquatic and sub-aquatic species possibly points to some special means of dispersal, perhaps migrating birds. The Himalayan-European distribution of living West European, and of many exotic, species, lends very strong confirmation to a suggestion made by us in 'The Pliocene Floras.' It is worth quoting what we there stated (pp. 22, 23):—'The immense area of high land in Central Asia, including Tibet, the Himalaya, and Western China, may have acted as a second centre for the origin and dispersal of temperate species, which radiated from these uplands when the climate became colder, just as they radiated from the shores of the Arctic Sea. If such a dispersal as this took place it must have been in Miocene or Pliocene times, when the Northern Hemisphere was cooling.'

I have already pointed out that the curve indicates the middle of the Miocene as the period at which the process of infiltration of the new flora began, to continue throughout the whole of the Pliocene.

It is clear, therefore, that the further work on Pliocene floras has strongly confirmed our suggestion, that the immense upland area of Asia formed a subsidiary centre of dispersal in the Pliocene; and it seems very probable, although I am not prepared to say that the suggestion is established, that much of the living flora of the lowlands of Western Europe has been derived from this source, by dispersal through the Near East, the Caucasus, and the mountains of Southern and Central Europe, or by way of the Mediterranean.

The incoming flora, which gradually supplanted the Chinese-North American flora, from the middle of the Miocene onwards, needs further analysis.

To ascertain how its character changed throughout the Pliocene Epoch, it is necessary in the first place to find its total percentage at the different stages. These are given by the complementary percentages to those of the Chinese-North American element. Next, the percentages of the exotic element must be found by subtracting the Chinese-North American percentage from those of the total exotic flora. The following table is then arrived at:—

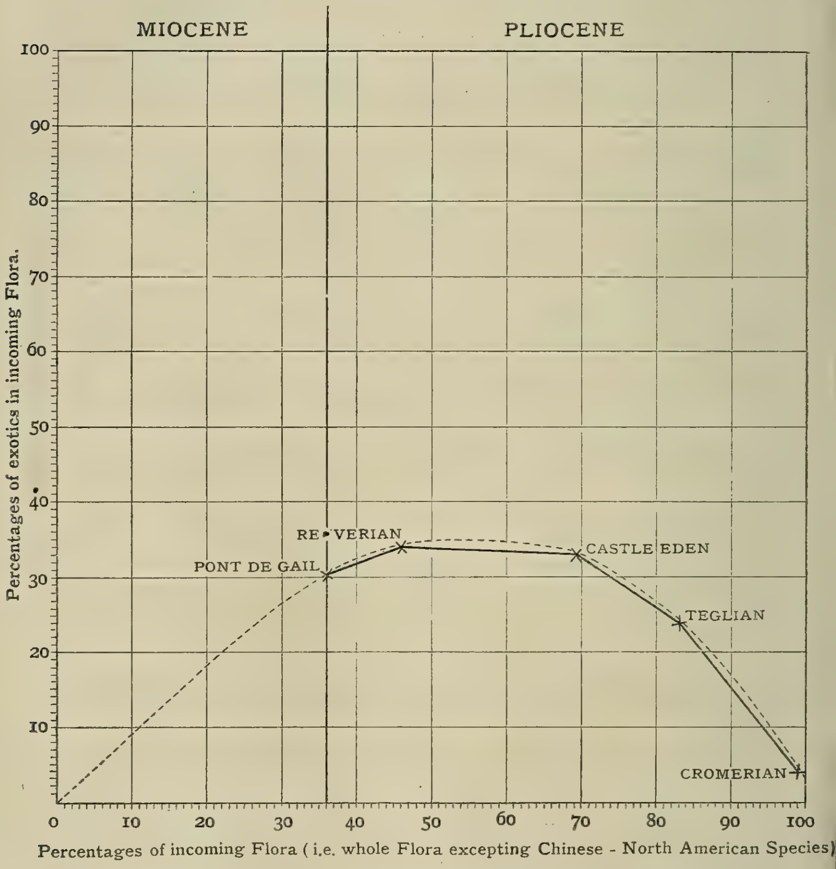
Table showing the Change in Character of the Incoming Flora.

Flora.	*Percentage of total incoming flora.*	*Percentage of exterminated element in it.*
Cromerian	96·26	5
Teglian	84	24
Castle Eden	69	33
Reuverian	46	34
Pont-de-Gail	36	30

If the figures of these two columns are then plotted as a curve (fig. 2, p. 154) they show the general character of the change of this incoming flora. In this curve the zero-point corresponds to

the point given by the *loci* of 100 in the other (fig. 1, p. 150): that is, the point at which the incoming flora began to enter. Although it made good headway against the already established Chinese-North American flora, by no means all of it was destined to survive. Of the first species to enter, hardly any survived to

Fig. 2.—*Percentage relation between the entire incoming flora and the exotic part of it.*



the end of the Pliocene. In the time of the Pont-de-Gail flora, though the incoming flora formed more than a third of the whole West European flora, yet only a sixth of it was destined to survive to the end of the Pliocene; in the Reuverian it formed nearly half the flora, and of this nearly three-quarters was exterminated;

in the Castle-Eden deposit it formed seven-tenths of the whole flora, and nearly half of this was exterminated.

The generalization of these facts shown in the curve, makes it appear that those elements of the incoming flora which entered earlier were destined to ultimate extirpation in a much greater degree than those which entered later, though for a time they were able to maintain their position. The percentage of the exterminated element steadily increased, until, during the Lower Pliocene and beginning of the Middle Pliocene age, it maintained a fairly-even proportion of about one-third of the whole flora; after which period it gradually declined.

The fact that this exotic element of the incoming flora did gain a considerable footing, means that, although the West European flora was rather rapidly losing its Chinese-North American character through Miocene and early Pliocene times, yet it was still almost entirely an exotic flora.

IV. Conclusions.

Such are the deductions to which the study of Pliocene seeds has led. In conclusion, I would suggest that imperfect though these curves may be, resting as they do upon my own imperfect knowledge and judgment, they nevertheless point to the perfect, the absolute, curve, which shall trace the true course of events. They show that by the application of graphic methods to palæobotany it should be possible to arrive at broad and accurate generalizations, which may not only be a help to present methods of research, but may even indicate new fields for investigation.

But if such work is to be done, it must rest upon the gathered knowledge of many workers. As yet it is but in its infancy; of this no one can be more aware than myself. If, however, fossil-seeds are to be studied, and I hope that I have made good the claim that they should be studied, both by geologists and by botanists, then we must have seed-collections, so arranged and displayed that they can readily be seen and examined microscopically. For it is not with seeds as with flowers: these have been described and classified, and can be traced, at least in the earlier stages of the determination, by reference to books. Seeds and endocarps must be sought for by the eye. If you cannot see them—what then? A pea in its pod, or a stone in its berry, for any possibility of comparison, might almost as well be under lock and key.

I know that in these days of stress it may be impossible to carry out this work, but I hope that in the future the time may come when it can be taken in hand.

V. Lists of Species selected for Comparison from each of the Five Pliocene Deposits.

[* = Chinese-North American association; ** = other exotics.]

Cromerian List.

Osmunda regalis Linnæus.
Pinus silvestris Linnæus.
Picea excelsa Link. **
Taxus baccata Linnæus.
Sparganium ramosum Hudson.
Potamogeton crispus Linnæus.
P. heterophyllus Schreber.
P. natans Linnæus.
P. obtusifolius Mertens & Koch.
P. pectinatus Linnæus.
P. perfoliatus Linnæus.
P. prælongus Wulf.
P. pusillus Linnæus.
P. trichoides Chamisso.
Naias marina Linnæus.
N. minor Allioni. **
Zannichellia palustris Linnæus.
Z. pedunculata Reichenbach.
Sagittaria sagittifolia Linnæus.
Alisma plantago Linnæus.
Stratiotes aloides Linnæus.
Phragmites communis Trinius.
Eriophorum vaginatum Linnæus.
Scirpus fluitans Linnæus.
S. lacustris Linnæus.
S. tabernæmontani Gmelin.
Carex acutiformis Ehrhardt.
C. dioica Linnæus.
C. helodes Link.
C. hirta Linnæus.
C. muricata Linnæus.
C. riparia Curtis.
C. rostrata Stokes.
C. vesicaria Linnæus.
Salix cinerea Linnæus.
Carpinus betulus Linnæus.
Corylus avellana Linnæus.
Betula alba Linnæus.
Alnus glutinosa Gærtner.
Fagus silvatica Linnæus.
Quercus robur Linnæus.
Ulmus campestris Linnæus.
Urtica dioica Linnæus, var.? *
U. urens Linnæus.
Rumex acetosella Linnæus.
R. acutus Linnæus.
R. hydrolapathum Hudson.
R. maritimus Linnæus.
R. obtusifolius Linnæus.
Polygonum amphibium Linnæus.
P. aviculare Linnæus.
P. convolvulus Linnæus.
P. persicaria Linnæus.
Chenopodium album Linnæus.
C. rubrum Hudson.
Atriplex hastata Linnæus.
Stellaria aquatica Mœnch.
S. holostea Linnæus.
S. media Villars.
Arenaria serpyllifolia Linnæus.
Nuphar luteum Smith.
Nymphæa alba Linnæus.
Ceratophyllum demersum Linnæus.
Caltha palustris Linnæus.
Ranunculus aquatilis Linnæus.
R. flammula Linnæus.
R. lingua Linnæus.
R. nemorosus De Candolle. **
R. repens Linnæus.
R. sceleratus Linnæus.
Thalictrum flavum Linnæus.
Hypecoum procumbens Linnæus. **
Spiræa ulmaria Linnæus.
Pyrus aria Ehrhardt.
P. malus Linnæus.
Mespilus monogyna Jacquin.
M. oxyacantha Linnæus.
Rubus fruticosus Linnæus.
R. idæus Linnæus.
Potentilla silvestris Necker.
Alchemilla arvensis Scopoli.
Prunus spinosa Linnæus.
Euphorbia amygdaloides Linnæus.
Corema intermedia Reid. **
Acer campestre Linnæus.
Rhamnus frangula Linnæus.
Hypericum hirsutum Linnæus.
H. quadrangulum Linnæus.
Elatine hydropiper Linnæus.
Viola hirta Linnæus.
V. palustris Linnæus.
V. riviniana Reichenbach.
Trapa natans Linnæus. **
Circæa lutetiana Linnæus.
Myriophyllum spicatum Linnæus.
Hippuris vulgaris Linnæus.
Chærophyllum silvestre Linnæus.
Torilis anthriscus Bernhardi.
Conium maculatum Linnæus.
Cicuta virosa Linnæus.
Œnanthe lachenalii C. C. Gmelin.
Œ. phellandrium Lamarck.
Æthusa cynapium Linnæus.
Pastinaca sativa Linnæus.
Heracleum sphondylium Linnæus.
Cornus sanguinea Linnæus.

Menyanthes trifoliata Linnæus.
Ajuga reptans Linnæus.
Prunella vulgaris Linnæus.
Ballota nigra Linnæus.
Stachys arvensis Linnæus.
S. silvatica Linnæus.
Calamintha arvensis Linnæus.
Lycopus europæus Linnæus.
Mentha aquatica Linnæus.
Solanum dulcamara Linnæus.
Verbascum thapsus Linnæus.
Limosella aquatica Linnæus.
Veronica chamædrys Linnæus.
Littorella juncea Bergeret.
Galium aparine Linnæus.
Viburnum opulus Linnæus.
Valerianella olitoria Pollich.
Valeriana sambucifolia Willdenow.
Eupatorium cannabinum Linnæus.
Bidens tripartita Linnæus.
Tussilago farfara Linnæus.
Arctium lappa Linnæus.
Carduus heterophyllus Linnæus.
C. nutans Linnæus.
C. palustris Willdenow.
Centaurea calcitrapa Linnæus.
Picris hieracioides Linnæus.
Crepis succisæfolia Tausch.
Leontodon autumnalis Linnæus.

TEGLIAN LIST.

Equisetum ramosissimum Desfontaines. **
Juniperus sp. **
Sparganium ramosum Hudson.
Potamogeton acutifolius Link.
P. coloratus Hornemann.
P. crispus Linnæus.
P. pectinatus Linnæus.
P. pusillus Linnæus.
Naias marina Linnæus.
N. minor Allioni. **
Sagittaria sagittifolia Linnæus.
Alisma plantago Linnæus.
Stratiotes aloides Linnæus.
Cyperus sp. 1. **
Cyperus sp. 2. **
Scirpus lacustris Linnæus.
S. tabernæmontani Gmelin.
Dulichium vespiforme Reid. *
Carex echinata Murray.
C. hirta Linnæus.
C. riparia Curtis.
Pterocarya limburgensis Reid. *
Carpinus betulus Linnæus.
Carpinus sp. **
Alnus viridis Chaix. **
Urtica dioica Linnæus var.? *
U. urens Linnæus.
Pilea pumila Asa Gray. *
Rumex acetosella Linnæus.
R. maritimus Linnæus.
R. obtusifolius Linnæus.
Polygonum bellardi Allioni. **
P. convolvulus Linnæus.
P. lapathifolium Linnæus.
P. minus Hudson.
Chenopodium rubrum Hudson.
C. urbicum Linnæus.
Atriplex patula Linnæus.
Stellaria aquatica Mœnch.
S. nemorum Linnæus.
Lychnis flos-cuculi Linnæus.
Euryale limburgensis Reid. *
Ceratophyllum demersum Linnæus.
Aquilegia vulgaris Linnæus.
Clematis vitalba Linnæus.
Ranunculus aquatilis Linnæus.
R. nodiflorus Linnæus. **
R. repens Linnæus.
R. sceleratus Linnæus, var.? *
Thalictrum bauhini Crantz. **
Magnolia kobus De Candolle. *
Magnolia sp. *
Mespilus cuneata Siebold & Zuccarini. *
Rubus cf. *pungens* Cambessèdes. *
Potentilla argentea Linnæus.
Prunus cf. *lusitanica* Linnæus. **
P. maximoviczii Ruprecht. *
P. spinosa Linnæus.
Phellodendron elegans Reid. *
Corema intermedia Reid. **
Staphylea sp. 1. **
Staphylea sp. 2. **
Acer campestre Linnæus.
A. opulifolium Villars? **
A. limburgense Reid. **
Vitis vinifera Linnæus. **
Menispermum dahuricum De Candolle. *
Actinidia faveolata Reid. *
Hypericum androsæmum Linnæus.
H. perforatum Linnæus.
H. pulchrum Linnæus.
Viola arvensis Murray.
Trapa natans Linnæus. **
Myriophyllum verticillatum Linnæus.
Araliaceæ, genus? *
Hippomarathrum sp. **
Cryptotænia sp. *
Petroselinum segetum Koch.
Cicuta virosa Linnæus.
Laserpitium siler Murray. **
Erica cf. *vagans* Linnæus. **
Verbena officinalis Linnæus.
Teucrium botrys Linnæus.

Teucrium scordium Linnæus.
Prunella vulgaris Linnæus.
Stachys longiflora Boissier & Balansa. **
S. silvatica Linnæus.
Melissa officinalis Linnæus.
Calamintha sp. **
Origanum vulgare Linnæus.
Thymus serpylum Linnæus.
Lycopus europæus Linnæus.
Mentha aquatica Linnæus.
Physalis alkekengi Linnæus.
Solanum dulcamara Linnæus.
Veronica chamædrys Linnæus.
Valeriana tripteris Linnæus. **
Bidens tripartita Linnæus.
Carduus nutans Linnæus.
C. palustris Willdenow.

Castle-Eden List.

Sparganium ramosum Hudson.
Potamogeton acutifolius Link.
P. pectinatus Linnæus.
P. natans Linnæus.
Naias minor Allioni. **
Alisma plantago Linnæus.
Cyperus sp. 1. **
Cyperus sp. 2. **
Cladium sp. **
Scirpus cf. *tabernæmontani* Gmelin.**
Carex glauca Scopoli.
Carpinus laxiflora Blume. *
Betula alba Linnæus.
Alnus glutinosa Gærtner.
A. viridis De Candolle. **
Urtica dioica Linnæus, var. ? *
Pilea pumila A. Gray. *
Rumex acetosella Linnæus.
Chenopodium urbicum Linnæus, var. ? **
Stellaria aquatica Mœnch.
Ranunculus (*Batrachium*) sp. **
R. nodiflorus Linnæus. **
R. lateriflorus De Candolle ? **
R. sceleratus Linnæus, var. ? *
Ranunculus sp. **
Alliaria sp. **
Chrysosplenium sp. *
Liquidambar sp. **
Spiræa ulmaria Linnæus.
Spiræa sp. **
Cratægus acuticarpa Reid. *
C. microcarpa E. M. Reid. *
C. nodulosa E. M. Reid. *
Potentilla argentea Linnæus.
P. pliocenica E. M. Reid. **
Rubus lasiostylus Focke. *
R. adenophorus Rolfe. *
R. cratægifolius Bunge. *
Oxalis corniculata Linnæus. **
Rhus dunelmensis E. M. Reid. *
Rhus sp. **.
Ilex oblongum E. M. Reid. *
Viola palustris Linnæus.
V. silvestris Reichenbach.
V. vaginata Maximowicz. *
Hippuris vulgaris Linnæus.
Aralia cordata Thunberg. *
Erica cf. *vagans* Linnæus. **
Gentiana sp. *
Ajuga decumbens Thunberg. *
Sideritis sp. **
Prunella vulgaris Linnæus.
Melissa elegans E. M. Reid. *.
Thymus serpylum Linnæus.
Clinopodium nepeta O. Kuntze.
Inula conyza De Candolle.
Pulicaria dysenterica Gærtner.

Reuverian List.

Picea excelsa Link. **
Larix europæa De Candolle.
Sequoia sp. *
Gnetum scandens var. *robustum* Reid. *
Sparganium cf. *ramosum* Hudson. **
S. cf. *minimum* Fries. **
S. noduliferum Reid. **
Naias marina Linnæus.
Sagittaria sagittifolia Linnæus.
Alisma plantago Linnæus.
Scirpus carinatus Asa Gray. *
S. lacustris Linnæus, var. ? **
S. mucronatus Linnæus. **
S. tabernæmontani Gmelin.
Cladium mariscus Robert Brown.
Dulichium spathaceum Richard. *
D. spathaceum var. *marginatum* Reid. *
Dulichium spathaceum var. *ellipticum* Reid. *
D. vespiforme var. *triangulare* Reid. *
D. urceolatum Reid. *
D. urceolatum Reid, var. *
Dulichium (?), sp. nov. *
Epipremnum crassum Reid. *
Epipremnum sp. *
Pterocarya limburgensis Reid. *
Carya angulata Reid. *
Carpinus betulus Linnæus.
Corylus avellana Linnæus.
Betula digitata Reid. *
Fagus decurrens Reid. **
Fagus sp. **
Quercus robur Linnæus.
Zelkowa keaki Linnæus. *
Urtica dioica var. *

Urtica urens Linnæus.
Hakea angulata Reid. *
Pyrularia edulis De Candolle. *
Aphanisma. *
Nelumbium minimum Reid. *
Brasenia peltata Pursh. *
B. tuberculata Reid. *
Nuphar canaliculatum Reid. **
Euryale nodulosa Reid. *
E. lissa Reid. *
Clematis grata Wallich. *
Ranunculus brutius Tenore. **
R. lateriflorus De Candolle. ? **
R. nemorosus De Candolle. **
Thalictrum bauhini Crantz. **
T. simplex var. *galioides* Nestler. **
Magnolia kobus De Candolle. *
Liriodendron aptera Reid. *
L. tulipifera Linnæus. *
Cinnamomum sp. 1. *
Cinnamomum sp. 2. *
Cinnamomum sp. 3. *
Bucklandia striata Reid, *
Liquidambar orientale Miller, var. ? **
Corylopsis limburgensis Reid. *
Hamamelidaceæ, genus (?) *
Cratægus acuticarpa Reid. *
Pyrus malus Linnæus, var. **
P. cf. *malus.* **
Mespilus monogyna Jacquin.
Rubus cf. *fruticosi.* **
R. cf. *pungens* Cambessèdes. *
Prunus maximoviczii Ruprecht. *
P. spinosa Linnæus.
P. cf. *spinosa* Linnæus. **
P. spinulosa Siebold & Zuccarini. *
P. tenuiputamenta Reid. **
Prunus sp. 4. *
Wistaria sp. *
Biebersteinia sp. nov. **
Orixa reticulata Reid. *
Ruta sp. **
Phellodendron elegans Reid. *
P. tessellatum Reid. *
Coriariaceæ. **
Pistacia acuminata Reid. **
Ilex aquifolium Linnæus.
Acer cf. *lobelii* Pax. **
A. striatum Reid. *
Æsculus spinosissima Reid. **
Meliosma europæa Reid. *
Karwinskia paucicostata Reid. *
Berchemia sp. *
Rhamnus sp. *
Rhamnaceæ, genus nov. (?). *
Vitis vinifera Linnæus. **
V. orientalis Boissier. **
Actinidia faveolata Reid. *
Stewartia pseudo-camellia Maximowicz. *
Hypericum cf. *ascyron* Linnæus. *
Viola cf. *rupestris* Schmidt. **
Scyphallandra. *
Nyssa silvatica Marsh. *
Camptotheca crassa Reid. *
Trapa natans Linnæus. **
Circæa crassa Reid. **
Proserpinaca reticulata Reid. *
Myriophyllum verticillatum Linnæus.
Hippuris globosa Reid. **
Hippuris sp. **
Aralia racemosa Linnæus. *
Araliaceæ, genus (?). *
Petroselinum sp. **
Cicuta virosa Linnæus.
Cornus controversa Hemsley. *
C. cf. *mas* Linnæus. **
Helwingia sp. *
Monotropa sp. **
Mæsa sp. *
Ardisia sp. *
Trientalis sp. **
Mimusops septentrionalis Reid. *
Diospyros lotus Linnæus. **
Diospyros sp. 2. **
Styrax mucronatum Reid. *
Jasminum contiguum Reid. **
J. undulatum Ker-Gawler ? *
Ajuga antiqua Reid. **
Sideritis scordioides Linnæus. **
Lycopus europæus Linnæus.
Hancea sp. *.
Melissa elegans Reid. *
Sambucus pulchella Reid. *
Ecballium, sp. nov. **
Eupatorium japonicum Thunberg, var. *
Crepis blatteroides Villars. **
C. fuscipappa Bentham. *

PONT-DE-GAIL LIST.

Sparganium ovale E. M. Reid. **
Stratiotes tuberculatus E. M. Reid. **
Epipremnum crassum Reid. *
Carpinus sp. **
Polygonum convolvulus Linnæus.
Fagopyrum pliocenicum E. M. Reid. *
Ranunculus gailensis E. M. Reid. **
Menispermum cantalense E. M. Reid. *
Polanisia rugosa E. M. Reid. *
Vitis lanata Roxburgh. *
Myriophyllum cylindricum E. M. Reid. **
Symplocos jugata E. M. Reid. *
S. urceolata E. M. Reid. *
S. microcarpa E. M. Reid. *
Lycopus antiquus E. M. Reid. *
Sambucus pulchella Reid. *
Trichosanthes fragilis E. M. Reid. *

Discussion on the two foregoing Papers.

Prof. A. C. Seward said that he regarded it a privilege to have heard the Author's admirable account of her recent researches; he had never listened to a palæobotanical communication to the Society with greater interest, or with fuller confidence. He asked whether the Mediterranean Sea might not have formed the barrier to the Southern migration of the Chinese-North American plants rather than the Alpine ranges. The speaker felt sure that Fellows who had previously doubted the value of fossil seeds as criteria of affinity would be compelled to alter their opinion after the Author's convincing demonstration. He expressed the hope that a national collection of seeds and fruits would be provided.

Prof. James Small emphasized the degree of accuracy which is possible in the determination of fossil seeds and fruits. Having been privileged with an opportunity of examining some fossil fruits of Compositæ (sent to him by Mrs. Reid), he found that he could distinguish between varieties of the same species, and that he could even detect microscopical differences in the cells of the fruit-wall in specimens of the same recent species grown at La Mortola and at Cambridge, the former being identical with the fossil specimens from Castle Eden, while the latter could easily be distinguished from the fossils. He explained that, from being a botanical sceptic, he had become a complete convert to the value of the study of seeds and fruits, both recent and fossil.

Mr. M. M. Allorge expressed the opinion that the Author's papers were of great interest, not only to geologists, but also to botanists and geographers. It was a well-known fact that a large portion of China was covered with deposits of lœss; these æolian deposits occurred chiefly along the eastern margin of the present centre of high barometric pressure of Siberia. If the present Chinese-North American flora were associated with the lœss, was it plausible to infer, from the presence of numerous exotic Chinese plants in Western Europe during the Pleistocene Epoch, that at that period the climatic conditions in Western Europe were also favourable to the formation of the lœss?

Dr. C. W. Andrews and Sir Henry Howorth also spoke.

The Author thanked the speakers for the very kind reception that they had given to her papers. In reply to Prof. Seward, she said that if it had been the Mediterranean, not the transcontinental mountains, which formed the barrier to the southward migration of the Chinese-North American association of plants, the West European Pliocene floras would have shown a closer relationship with the living flora of the Mediterranean region than was the case: Mediterranean species occur very rarely in the West European Pliocene floras. With reference to Sir Henry Howorth's very just statement that Asa Gray recognized the closest alliance of the Japanese flora to be with that of the

Eastern United States, the Author stated that she had not been able to trace this regional relationship in the Pliocene of Western Europe. The relationship appeared to be as close with the flora of the Western, as with that of the Eastern United States. She thought it possible that the regional alliance spoken of by Asa Gray might, in part, be due to extermination of species on the great plains of the United States during subsequent Pleistocene migrations, when the change of climate from cold to warmth was fairly rapid, and might have overtaken the rate of travel of the migrating flora.

5. *On* Syringothyris *Winchell, and* Certain Carboniferous Brachiopoda referred to Spiriferina *D'Orbigny.* By

Frederick John North, D.Sc., F.G.S., Geological Department, National Museum of Wales, Cardiff. (Read January 7th, 1920.)

[Plates XI–XIII.]

Contents.

I. Introduction.

In this paper an attempt is made to remove the uncertainty which has hitherto existed in the naming of the British species of *Syringothyris* and of certain Carboniferous brachiopoda referred to the genus *Spiriferina*.

Recent zonal work on the Carboniferous Limestone has demonstrated the desirability of (1) a more accurate knowledge of the essential characters of *Syringothyris*, and (2) of distinguishing names for the forms occurring at various horizons. In the case of the Spiriferids with a lamellose surface-ornament, it has been customary to refer them all to *Spiriferina*, because there was no other genus for their reception—although it had long been recognized that few, if any of them, really belonged to that genus.

When this investigation was commenced some years ago, it was intended to deal exhaustively with all the British Carboniferous shells referred to *Syringothyris* and *Spiriferina*, together with the relation of the latter to their pre-Carboniferous and post-Carboniferous representatives, and a preliminary paper dealing

with the generic characters of *Syringothyris* was published in 1913.[1] Since that time, however, various circumstances have prevented its completion; and, when I resumed the work after returning to civil life, it seemed desirable to publish the results already obtained, leaving certain undecided matters relating to the extra-Carboniferous forms to be dealt with in a subsequent paper.

As it now stands, the paper includes:—

(1) A general account of the genus *Syringothyris*.

(2) A discussion of the British species of that genus and their classification: the detailed consideration of the remarkable forms which occur in the Waulsortian knoll-phase limestones of the *Caninia* Zone in Ireland is deferred, until the return of favourable conditions renders further field-work possible.

(3) A discussion of the generic position of '*Spiriferina*' *laminosa* (M'Coy), and of the relation between the genus represented by that species and *Syringothyris*.

(4) Notes on *Spiriferina*, and certain Carboniferous Spiriferids possessing a lamellose surface-ornament.

The material used in the course of this work was in part collected by myself, but for the opportunity of examining a good deal of it I am indebted to the kindness of other workers, who have either lent me material of their own collecting, or have given me facilities for studying specimens in their care. Among the former are the late Mr. C. H. Cunnington, the late Dr. Wheelton Hind, Mr. F. Dixey, Mr. J. W. Jackson, Mr. J. F. Jackson, Mr. L. B. Smythe, and Mr. J. W. Tutcher, Prof. E. J. Garwood, Prof. S. H. Reynolds, and Principal T. F. Sibly; the latter include Mr. H. A. Allen, Prof. G. A. J. Cole and Mr. W. B. Wright (Geological Survey, Dublin), Dr. F. R. Cowper Reed and Mr. H. Woods (Sedgwick Museum, Cambridge), Dr. A. Smith Woodward and Mr. R. B. Newton (British Museum, Natural History), and Dr. R. F. Scharff (National Museum, Dublin).

My thanks are also due to Dr. F. A. Bather for his advice upon a matter of nomenclature, to Mr. S. S. Buckman for suggestions relating to parts of the paper, to Principal T. F. Sibly for his ever-ready advice and encouragement, and to Dr. F. L. Kitchin for his kindness in reading and criticizing the manuscript.

Explanation of Certain Terms used.

In order to avoid ambiguity and unnecessary repetition in the text, the precise meaning which is attached to certain frequently recurring terms is indicated in the following paragraphs:—

I. Terms applied to External Characters.

Cardinal area.—A more or less well-developed triangular area on each side of the delthyrial fissure, distinctly marked off from the general surface of the shell. A cardinal area may be present in either valve, but that in the brachial valve is usually inconspicuous. In this paper 'cardinal area' always refers to that of the pedicle-valve.

[1] North [25]. (Numbers in brackets refer to papers enumerated in the Bibliography, § VIII, p. 224.)

Apical angle.—The angle enclosed at the apex of the cardinal area.

Delthyrial angle.—The angle enclosed by the sides of the delthyrial fissure.

Cardinal extremities.—The terminations of the hinge-line.

Lateral slopes.—Those portions of the surface of both valves which lie on either side of the fold in the brachial valve and the sinus in the pedicle-valve.

Costæ.—The components of the radial ornament of the shell of *Syringothyris* and other brachiopoda have usually been termed 'ribs' and, less frequently, 'costæ.' In order to assist in securing uniformity in terminology, it is proposed to adopt the suggestion of the late Dr. Ivor Thomas, and to use only the term 'costæ' in this connexion. As that author pointed out,[1] 'the radially disposed features hitherto called ribs appear to correspond to the "spirals" of gasteropoda,' and certainly not to their ribs, which are concentric in their arrangement.' On these grounds he used the term 'ribs' for the concentric rugæ of the *Producti*, and 'costæ' for the components of the radial ornament.

II. Terms applied to Internal Characters.

Delthyrial supporting-plates.—The delthyrial supporting-plates are a pair of lamellæ in the pedicle-valve, which project from the edges of the delthyrium into the interior of the shell. These plates were formerly termed 'dental plates,' because they were supposed to exist for the support of the teeth; but the late Dr. Ivor Thomas, discussing their function in *Orthotetes*, proposed the term[2] 'delthyrial supporting-plates': and since, in the shells under consideration, the plates have almost disappeared long before they reach the hinge-line, it would seem that their primary function is not to support the teeth, but to strengthen and support the thin shell of the cardinal area where it is interrupted by the delthyrial fissure.

Median septum.—Vertical shelly septa may exist in the longitudinal median plane of either valve; and where, in order to avoid confusion, it is necessary to distinguish between them, the terms 'ventral median septum' and 'dorsal median septum' may be used.

Ventral median septum.—In many brachiopoda the muscular scars in the pedicle or ventral valve are bisected by a distinct ridge, which in some genera becomes an elevated shelly plate or septum rising into the cavity of the shell, and extending farther towards the anterior margin than do the delthyrial supporting-plates on either side of it (see text-fig. 1, *m*, *n*, *o*, *p*, p. 166). The function of the septum was presumably to afford additional surface for the attachment of the adductor muscles, the scars of which extend over its sides.[3] The presence or absence of a ventral median septum, and its nature when present, are important taxonomic characters in the group of shells under consideration.

Dorsal median septum.—This is never more than a low ridge in the genera here discussed, and it is of no value in discriminating between species.

Apical callosity.—There is frequently a tendency to an excessive deposition of shelly matter in the apical portion of the pedicle-valve, which becomes greatly thickened, or even completely solidified. Hall & Clarke described this character as the 'apical callosity,' and it was referred to by the late Dr. A. Vaughan as the 'rostral callus.'

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[1] 'British Carboniferous Producti' Mem. Geol. Surv. Gt. Britain, Palæontology, vol. i, pt. 4 (1914) pp. 225–26.

[2] 'The British Carboniferous Orthotetinæ' Mem. Geol. Surv. Gt. Britain, Palæontology, vol. i, pt. 2 (1910) pp. 100–101.

[3] J. Hall & J. M. Clarke [14] p. 53, fig. 42. The occurrence of the muscular scars on the sides of the ventral median septum has been recorded in *Spiriferina walcotti* by Hall & Clarke, *op. cit.*, and in *Sp. octoplicata* by W. King, 'Monogr. Perm. Foss.' Pal. Soc. 1850, p. 68.

The apical callosity usually increases with the age of the individual, and in ephebic shells completely envelops the earlier-formed portions of the delthyrial supporting-plates and associated structures. Although few of the Spiriferid shells are entirely without an apical callosity, the structure is especially well developed in certain species. When present, it gives a very characteristic appearance to internal casts of the pedicle-valve (see Pl. XIII, fig. 12).

Transverse plate and syrinx.—The transverse plate is an horizontal septum between the delthyrial supporting-plates, and projecting into the interior of the shell from the anterior end of the apical callosity. It may exist as a simple horizontal lamella, or, as in *Syringothyris*, it may bear on its lower surface a split tube or syrinx. (See fig. 1 *b*, p. 166.)[1]

II. Syringothyris Winchell.

(*a*) History of Previous Research.

The earliest account of a species now referred to *Syringothyris* was given by William Martin in 1796, when he described *Anomia cuspidata* from the 'Limestone' of Castleton (Derbyshire).[2] Thirteen years later he again described and figured *Conchyliolithus anomites cuspidatus* in his 'Petrifacta Derbiensia,'[3] but dealt only with the external characters of the shell, there being nothing in his specimen to suggest the existence of internal structures. Martin compared the shell to the recent *Anomiæ*, and suggested that the large triangular area was the surface of attachment, and that the muscles of fixation passed through the narrow fissure (that is, the delthyrium).

Although several authors referred to and illustrated this remarkable shell during the following thirty years or so,[4] no additional characters were discovered until 1838, when G. P. Deshayes recorded the presence of a convex plate (deltidium) covering the delthyrial fissure. That author stated that the plate was provided near the apex with an oval foramen.[5]

A similar opinion was expressed by Thomas Davidson, who figured an internal cast of '*Spirifera cuspidata*'[6] from the

'dolomitic Carboniferous Limestone of Breedon Hill, in which there is evidence that the deltidium was in reality perforated by a circular foramen.'

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[1] The words 'upper' or 'lower,' and 'above' or 'beneath,' used in connexion with the transverse plate and syrinx, refer to the structures when the shell is held with the apex of the pedicle-valve away from the observer, and the beak of the brachial valve pointing upwards, as in the sections in fig. 1 (p. 166). They have no reference to the position of the shell during the life of the individual.

[2] W. Martin [22] p. 44 & pl. iii, figs. 1–4.

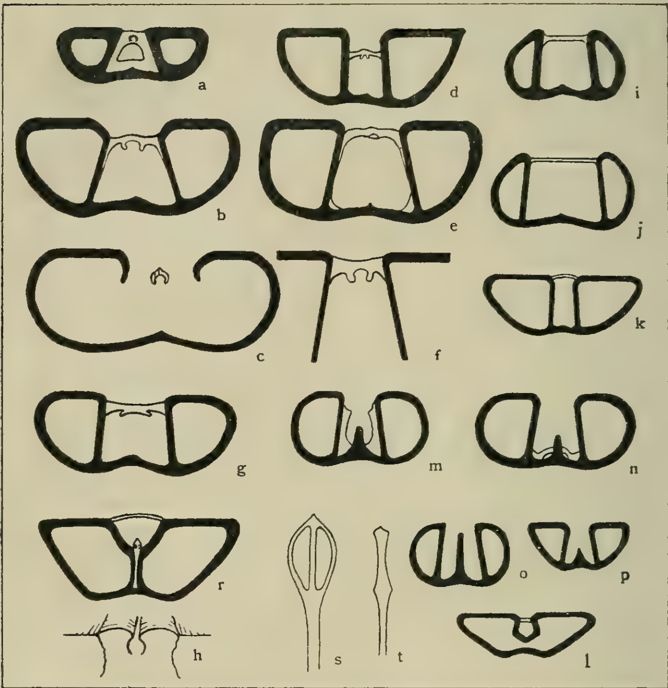
[3] W. Martin [23] pl. xlvi, figs. 3–4; pl. xlvii, fig. 5. Martin's type-specimen is now preserved in the Sowerby Collection, in the Geological Department of the British Museum (Natural History).

[4] J. Parkinson [26] vol. iii, pp. 234–35 & pl. xvi, fig. 17; J. Sowerby [33] pp. 42–44 & pl. cxx, figs. 1–3; J. Fleming, 'A History of British Animals' (1828) p. 563.

[5] Deshayes in 'Histoire Naturelle des Animaux sans Vertèbres' 2nd ed. vol. vii (1838) p. 368.

[6] Davidson [4] explanation of pl. viii, footnote, and pl. ix, figs. 1–2. The specimen is now in the Davidson Collection, in the British Museum (Natural History).

Fig. 1.—*Sections across the beak of the pedicle-valves in* Syringothyris *and other genera. (Natural size, except where otherwise stated.)*



a–c = *Syringothyris principalis* (K_1), 5, 11, and 15 mm. respectively from the apex.

d = *S. cuspidata* mut. *exoleta* (C), 13 mm. from the apex, at a stage comparable with (b). [Specimen in the British Museum (Natural History), Geological Department, Reg. B 316.]

e = *S. elongata* (D). Section at a stage comparable with (b).

f = *S. elongata* (C), 10 mm. from the apex, at a stage comparable with (b). [Specimen in the British Museum (Natural History), Geological Department, Reg. B 393.]

g = *Spirifer marcyi* Hall, after H. S. Williams.

h = The plate-system in a specimen incorrectly referred to *Sp. distans*, after Davidson [5] pl. xxxiii, figs. 4 & 5.

i–j = *Spirifer duplicicosta* (D_2), 3 and 6 mm. respectively from the apex; compare with (a) and (b).

k = *Sp. distans*, with section of the deltidium.

l = *Syringospira prima*, after E. M. Kindle.

m–n = *Tylothyris laminosa* (C), 3 and 6 mm. respectively from the apex.

o = *Spiriferina walcotti*. Section 3 mm. from the apex: compare with (c).

p = *Punctospirifer scabricosta* (S), 3 mm. from the apex: compare with (o).

r–t = *Cyrtina heteroclita* (r $\times$ 2); s–t, the median septum and its partitioned tube greatly enlarged: s, where completely developed; t. near its termination.

As a matter of fact, however, the specimen in question shows, not a foramen in the deltidium, but the remains of the rod-like portion of the matrix which originally filled the cavity of the syrinx (see Pl. XI, fig. 6). On the strength of the supposed possession of a perforated deltidial covering, M'Coy [1] and Davidson [2] both assigned *cuspidata* to the genus *Cyrtia*, an opinion which Davidson, at least, abandoned later.

In 1855, M'Coy referred to the discovery in *S. cuspidata* of an 'internal deep-seated pseudodeltidium, without perforation.' [3] Although, in the absence of a figure, the precise nature of this 'internal pseudodeltidium' cannot be determined. it was in all probability the 'transverse plate'; since it is quite clear from the context that it was a structure distinct from the ordinary delthyrial covering, for which M'Coy used the term 'external pseudo-deltidium.'

In 1859, L. G. de Koninck described and figured a specimen which he referred to '*Spirifer distans*' [4] from the Carboniferous Limestone of Visé, in which the transverse plate and syrinx were clearly shown, but the structure was not made the basis of a new genus.[5]

After the publication of Winchell's paper describing the characters of a new genus, *Syringothyris*, Davidson called attention to the fact that De Koninck had already made known the existence of similar structures, and gave what he (Davidson) described as enlarged drawings of the Belgian specimens.[6] These illustrations depict the syrinx as being composed of two plates applied to the inner sides of the delthyrial supporting-plates and curling under along the median line to enclose a tubular canal. incomplete both above and below (see fig. 1 *h*). This structure, as interpreted by Davidson, differed from the syrinx of *S. cuspidata*, which is split along its lower surface only.

Davidson's interpretation was, however. incorrect, for De Koninck's own figures, although small, clearly indicate a transverse plate and syrinx differing in no way from that of *S. cuspidata*. Davidson's figures also differ from De Koninck's, and from the conditions which obtain in *S. cuspidata*, in that the lamellæ which contribute to the formation of the split tube are drawn as if they were applied to the delthyrial supporting-plates at the level of the cardinal area, and extended all the way from the beak to the hinge-line, while in *S. cuspidata* the transverse plate plunges beneath the level of the area, and stops short some distance from the hinge-line. Apart from the question of the precise nature of the structures indicated

[1] M'Coy [21] p. 426. [2] Davidson [1] p. 470.

[3] M'Coy *ibid. loc. cit.*

[4] De Koninck [18] p. 50 & pl. ii, fig. 6.

[5] The specimen, as is shown elsewhere in this paper, was not correctly referred to *Spirifer distans.*

[6] Davidson [2] p. 312 & pl. xiv, figs. 7–9; also [5] p. 280 & pl. xxxiii, figs. 4–5.

by Davidson's figures, the drawings are obviously incorrect, because, although they are supposed to represent the same specimen seen from above and below, in his fig. 4 the lateral portions of the transverse plate are convex towards the area, while in his fig. 5 they are concave, so that the upper slit occurs at the bottom of a semicircular trough. In the circumstances, we can only regard Davidson's figures as misinterpretations of true Syringothyroid characters, and it then transpires that De Koninck was the first to call attention to the transverse plate and syrinx.

No reasonable grounds exist for supposing that there are two types of syrinx, the one occurring in *Syringothyris cuspidata* and the other in *Spirifer distans*: for, in addition to the evidence already adduced, the structures indicated in Davidson's figures have not since been observed in any other specimen, and it is shown elsewhere in this paper that *Spirifer distans* does not possess a syrinx at all.

In 1863, A. Winchell described a Spiriferid shell [1] (from the yellow sandstones lying beneath the Burlington Limestone [Lower Mississippian] at Burlington, Iowa (U.S.A.), which possessed a plate-system in the ventral valve similar to that already noticed by L. G. de Koninck; and, apparently unaware of that author's communication, made the character the basis of a new genus, to which he gave the name *Syringothyris*, with *S. typa* Winchell as the genotype. He described the syrinx-bearing plate in the following terms:—

'transverse plate connecting the vertical dental lamellæ, arched above, and beneath giving off a couple of median parallel lamellæ which are incurved so as to nearly join their inferior edges, thus forming a slit-bearing tube which projects beyond the limits of the plate from which it originated into the interior of the shell.'

Two years later, F. B. Meek announced the discovery of a similar structure in '*Spirifera cuspidata*' from Millicent (Kildare).[2]

In 1868, W. King published a 'Monograph of *Spirifer cuspidatus* Martin,' in which he described in detail the characters of the species, and figured a series of sections across the beak of the ventral valve at various distances from the apex, illustrating more clearly than had hitherto been done, the structure of the transverse plate and syrinx.[3]

The precise nature of the transverse plate and syrinx, and their relation to the delthyrial supporting-plates and to the apical callosity, was described by me in 1913.[4]

The classification of the American members of the genus has been discussed by Schuchert [5] and by Weller [6].

The shell-structure of *Syringothyris*.—The microscopic structure of the shell of *Syringothyris* gave rise to a discussion

[1] Winchell [38] p. 6.
[2] Proc. Acad. Nat. Sci. Philad. ser. 2, vol. ix (1865) p. 276.
[3] King [17] pp. 1–23.
[4] North [25] pp. 397–99.
[5] Schuchert [29].
[6] Weller [36].

between Carpenter, Davidson, King, and Meek, which, so far as the three first-named authors are concerned, developed into what was little less than a personal quarrel.

Owing to its mode of preservation, Martin's specimen retained no trace of the original shell-structure, for, as that author observed :—

'it is a complete change, evidently retaining the external shape and markings of the original, which has been displaced by limestone similar to that in which the fossil was lodged.' ([22] p. 46.)

Winchell stated that in *Syringothyris typa* the shell was fibrous and impunctate, but both Meek and Carpenter observed punctations in specimens of that shell sent by Winchell himself. Carpenter, corroborated by Davidson, maintained that the shell of *S. cuspidata* was impunctate; but King, on the other hand, claimed to have seen on the surface of a specimen from Tuam (Galway), in the collection at Queen's College, Galway, 'patches of faint slightly-raised oval impressions' which he compared with similar markings on the surface of *Dielasma hastata*, known to be a punctate shell. King was so certain that the shell of *S. cuspidata* was punctate, while Carpenter so emphatically denied the presence of punctæ, that Meek, who had proved the existence of punctations in an example of *S. cuspidata* from Millicent, suggested the possibility of there being two distinct forms included under one and the same specific name, of which one form possessed the internal plates of *Syringothyris* and a punctate shell-structure, while the other had no Syringothyroid characters and an impunctate shell. Later, Carpenter himself admitted the existence of punctations in some of the Millicent specimens, and inclined to the opinion already expressed by Meek.[1]

The shell of *Syringothyris* was undoubtedly punctate, and the reason for Carpenter's assertion to the contrary is not difficult to find. In many fossils from the Carboniferous Limestone the shell-substance has been recrystallized, and in such cases the external appearance of the shell remains unaltered, but its intimate structure is obliterated. Many specimens from Ireland and Derbyshire

[1] For this discussion, see the following papers:—W. King, 'Monograph of the Permian Fossils of England' Pal. Soc. 1850, p. 110; W. B. Carpenter, 'On the Intimate Structure of the Shells of the Brachiopoda' in Davidson [3] pp. 23–40, and 'On the Minute Structure of certain Brachiopod Shells' Ann. & Mag. Nat. Hist. ser. 2, vol. xvii (1856) pp. 502–506; F. B. Meek, 'Observations on the Microscopic Shell-Structure of *Spirifer cuspidatus* Sowerby . . . . .' Proc. Acad. Nat. Sci. Philad. ser. 2, vol. ix (1865) pp. 275–77; W. B. Carpenter, 'On the Perforate Structure of *Spirifer cuspidatus*' Ann. & Mag. Nat. Hist. ser. 3, vol. xix (1867) pp. 29–31; F. B. Meek, 'On the Punctate Shell-Structure of *Syringothyris*' Amer. Journ. Sci. ser. 2, vol. xliii (1867) pp. 407–408, also Geol. Mag. 1867, p. 315; W. B. Carpenter, 'On the Shell-Structure of *Spirifer cuspidatus*, & of Certain Allied Spiriferidæ' Ann. & Mag. Nat. Hist. ser. 3, vol. xx (1867) pp. 68–73; W. King, 'Notes on some Perforated Palæozoic Spiriferidæ' Geol. Mag. 1867, pp. 253–56; and T. Davidson, 'Perforate & Imperforate Brachiopoda' Geol. Mag. 1867, pp. 311–13.

are of this nature, and show no trace of punctæ; but, wherever the shells are suitably preserved, as (for example) in the *Zaphrentis* Zone in many parts of the South-Western Province, the punctate structure is quite evident.

(*b*) The Characters of the Genus.

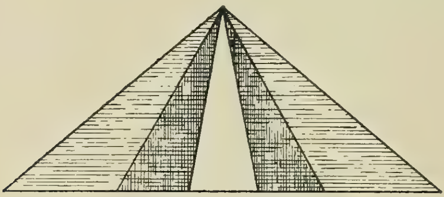
The shell of *Syringothyris* is Spiriferoid in form and variable in size. The dorsal valve is slightly convex; while the ventral valve is more or less acutely pyramidal, owing to the presence of a high cardinal area.

The hinge-line is straight, and the cardinal extremities are usually rounded, but are sometimes slightly produced and angular.

The cardinal area is high, and either slightly concave, flat, or even convex (see fig. 3, p. 178). In the holotype of *S. cuspidata* the area is practically flat. The apical angle varies, but the average for the genus is about 100°.

In well-preserved specimens the area is clearly differentiated into three regions by a pair of divergent lines extending from the apex to the hinge-line. The whole area is marked by horizontal striations representing lines of growth, and the central portion bears, in addition, vertical striations (see fig. 2).

Fig. 2.—*The threefold division of the area in* Syringothyris *(diagrammatic), based upon the specimen figured in Pl. XIII, fig. 2.*



The central region of the area is bisected by a triangular delthyrium about three times as high as wide. The delthyrial angle averages about 25°. The delthyrium is closed by a convex deltidium,[1] not perforated by a foramen as in *Cyrtia*. It is rarely preserved *in situ*, but there are two grooves along the sides of the delthyrium into which its edges are fitted.

In the brachial valve there is a distinct, but low, convex fold, and in the pedicle-valve a corresponding concave sinus which

[1] In a previous paper (North [25] p. 395) I used the term 'pseudo-deltidium' for this plate. I am indebted to Mr. H. Woods, F.R.S., for pointing out that Von Buch introduced the term 'deltidium' for the delthyrial covering-plate in the Telotremata, to which *Syringothyris* belongs, and that the use by American palæontologists of Bronn's term 'pseudodeltidium' in this sense is incorrect.

causes a wide rounded wave in the anterior margin. Except for a slight median depression on the fold, extending for a short distance from the beak of the brachial valve, the fold and sinus are smooth.[1]

The lateral slopes of each valve are typically ornamented by radial costæ, decreasing gradually in size towards the cardinal extremities. The costæ are regularly broad and depressed, and are separated by narrow, shallow furrows; they are always simple, and originate at the hinge-line, the last four or five on either side being small and inconspicuous. They are frequently obsolete, especially in the pedicle-valve, the lateral slopes of which may be quite smooth.

The costæ are crossed at irregular intervals by inconspicuous lines of growth, which are more closely crowded towards the margins of the valves. The external surface of the shell in suitably-preserved specimens is marked by a minute textile-like ornamentation, and the shell-substance is minutely punctate.

Internal structures: Pedicle-valve.—There is a pair of delthyrial supporting-plates which extend completely across the cavity of the valve, to the floor of which they are attached for about one-third of its length.

The transverse plate extends for from a third to half of the distance from the apex to the hinge-line, and has on its lower surface the split tube or syrinx.

'The transverse plate arises in the apex of the shell as an arch-shaped plate between, and applied to, the delthyrial supporting-plates . . . . The syrinx occurs on the lower surface of the plate, and is formed by two nearly-parallel lamellæ, the free ends of which curve towards one another. As the distance from the apex of the shell increases, the lateral portions of the arch become thinner and shorter, until only its roof persists as the tube-bearing or transverse plate—a slightly convex plate down the centre of which is a median ridge on the upper surface, and a slit tube or syrinx on the lower surface. The transverse plate itself then dies out. Its distal end is concave towards the apex of the valve, and the syrinx projects for a short distance beyond it'[2] (see figs. 1 *a*–1*c*, p. 166).

The earlier-formed portion of the syrinx tends to be obscured by the deposition of shelly matter (an apical callosity) during the growth of the shell (see fig. 1*a*, p. 166).

Brachial valve.—There is a low median septum extending for about half the length of the valve. Spiral coils are known to be present, but in the specimen in which they were developed by the Rev. Norman Glass, they were not *in situ*, and the nature of the primary lamellæ and jugum is, as yet, unknown.

The threefold division of the area.—In well-preserved specimens the area is clearly divided into three triangular portions, of which the two lateral portions are marked by horizontal striæ and are similar in intimate structure, namely, in the possession

[1] Two species with plicated fold and sinus have been referred to *Syringothyris*, but in neither case has the existence of a syrinx been proved. These are fully discussed elsewhere (see p. 189).

[2] North [25] pp. 398–99.

of punctæ, to the remainder of the shell. The central region, however, which is bisected by the delthyrium is impunctate, and in addition to the horizontal lines of growth, is marked by distinct, but irregularly-spaced, vertical striæ (see fig. 2, p. 170).[1]

The vertical striæ are the external indications of certain internal peculiarities of shell-structure. In partly-exfoliated specimens this peculiarity evinces itself in a series of trough-like depressions, which suggest that the shell-tissue of the cardinal area was traversed by numerous canals, perpendicular to the hinge-line. This, however, does not appear to have been the case, as no trace of a canal-system is apparent when thin sections of the area are examined under the microscope, and there is never any infilling by darker matrix such as is frequently the case with the tubular punctations of the shell of *Spiriferina walcotti*. The striæ are connected with a series of denticles along the hinge of the pedicle-valve, and articulate with a row of pits in the hinge-line of the opposite valve.

Davidson suggested that the function of the denticles was to steady the valves, especially when the hinge-line was long and the teeth not very large.[2] As the shell increased in size by the peripheral addition of shelly tissue, and the denticles receded from the apex, their course was marked by a series of lines, approximately parallel, and perpendicular to the hinge-line.

In a discussion of the origin of the vertical striæ, J. Young suggested that they were due to the presence in the hinge-line of the living animal of fibres of aragonite, which

> 'being harder than the ordinary calcite of the shell went to the formation of the row of denticles.'

If this were the case, the different degrees of resistance offered by the two minerals to subsequent alteration would account for the appearance of the canals in some specimens, for aragonite, although harder than calcite, is more soluble than that mineral.

The vertical striæ are only to be seen in specimens which have undergone but little mineralogical change, and they are often completely obliterated by recrystallization or exfoliation. The denticles are very rarely seen. Occasionally, as in the case of the specimen upon which Young's observations were based, the two valves are separated in such a way as to expose them clearly. In recrystallized specimens they have quite disappeared; but, according to Young, in some cases they are rendered visible by scraping and etching with acid. In this way he proved their existence in

[1] Dr. Ivor Thomas described in some of the Orthotetinæ 'a separate areal portion in the form of a raised triangular platform, marked off around the delthyrium. This secondary area is distinguished by vertical striations in contrast to the horizontal striations of the larger surrounding primary area.' In *Syringothyris*, however, the plane of the area is not interrupted by the central portion.

[2] J. Young, 'On the Denticulated Structure of the Hinge-Line of *Spirifera trigonalis*' Geol. Mag. 1884, pp. 18–20.

Sp. striata, and it is not unreasonable to assume their presence in all cases where there is a vertically striate area.

The taxonomic value of these vertical striations lies, not in their presence, but in their distribution on the cardinal area. In those species of *Spirifer* in which they have been observed, they occur over the whole area; but in *Syringothyris* they appear to be confined to the central portion of the area.[1]

There is a similar division of the area in *Spiriferina*. Unfortunately, owing to the mode of preservation of the shell, the vertical striations are not usually visible; but, when present, they afford a convenient means of distinguishing between *Syringothyris* and those species of *Spirifer*, such as *distans*, in which there is an elevated area.

(*c*) The Type Species of *Syringothyris*.

Three species have at different times, and by various authors, been regarded as the genotype of *Syringothyris*, namely:—*S. typa* Winchell, *S. cuspidata* (Martin), and *S. carteri* Hall.

Winchell, in establishing the genus, took as his type a form which he regarded as a new species, and to which he gave the name *typa*. A year later Meek suggested that Winchell's specimens were identical with *Spirifer cuspidatus* (Martin)[2]; and in 1867 W. King wrote:—

> 'It may be safely assumed that *Spirifer cuspidatus* and *Syringothyris typa* are one and the same species,' and 'it will necessarily follow that Martin's specific name, having priority, must be adopted in preference to the one proposed by Professor Winchell.'

This opinion was subsequently confirmed by Thomas Davidson.[3]

The two species, however, differ in the following respects:—

(1) The area of *typa* is relatively lower than that of *cuspidata* (as typified by the holotype); is slightly concave, but never reclined, as is frequently the case in Martin's species; and is always symmetrical, while that of *cuspidata* is frequently asymmetric or twisted.[4]

Winchell, in his diagnosis of *typa*, stated that the area was flat; but he probably used the term in a relative sense, for Davidson gave illustrations of specimens (provided by Winchell himself) which suggest that the area was slightly concave,[5] and Weller has also described the area of *typa* as concave with the curvature

[1] De Koninck described the threefold division of the area in a specimen of *Syringothyris*, and gave to the central portion the name 'pseudodeltidium complémentaire.' (De Koninck [18] p. 50 & pl. ii, fig. 5).

[2] In F. B. Meek & F. V. Hayden, 'Palæontology of the Upper Missouri' Smithson. Contrib. Knowl. vol. xiv (1865) p. 19.

[3] Davidson [5] p. 279.

[4] The comparison is based upon Martin's figures and the original specimen of *S. cuspidata* on the one hand, and on the other hand, Winchell's description of *S. typa*, together with figures given by Davidson and Weller.

[5] Davidson [2] pl. xiv, figs. 2 & 3.

towards the beak, while his figures of specimens from the same horizon as Winchell's lead to the same conclusions.[1]

(2) There are slight differences in the nature of the transverse plate and syrinx. In *S. cuspidata* (the holotype) the delthyrial supporting-plates are nearly parallel; the transverse plate is nearly flat, and diverges rapidly from the plane of the cardinal area, while in *S. typa* the delthyrial supporting-plates are distinctly divergent, and the transverse plate is convex upwards and never deeply buried.

Since, in addition to the above-mentioned differences, *S. typa* was derived from a low horizon in the Mississippian of North America (equivalent to the Lower Avonian of this country), and *S. cuspidata* (the holotype) from the Upper Avonian (*Dibunophyllum* Zone) of England, it seems desirable to regard them as distinct species, in which case *Syringothyris typa* remains as the genotype.

Schuchert expressed the opinion that *S. typa* is identical with a form previously described by James Hall as *Spirifer carteri*[2]; and, if that be so, the latter name has priority. The specimens upon which the species *carteri* was founded were fragmentary, poorly preserved, and comprised brachial valves only. Schuchert wrote:—

'I have seen nearly one hundred individuals and know of but two specimens that have both valves in articulation. Neither of these specimens shows the characteristic transverse plate of Winchell's genus. In several separated ventral valves, however, I have seen the canaliferous plate . . . so that there can be no doubt about *S. carteri* being a true *Syringothyris*.'

Despite the unsatisfactory condition of the material, Schuchert maintains that there is no visible difference between *S. typa* and *S. carteri* 'other than those due to the conditions of preservation, insufficient to separate them as distinct species.'[3]

Meek[4] and Herrick[5] also emphasized the similarity between *S. carteri* and *S. typa*, while the latter author regarded both names as synonymous with *S. cuspidata* Martin.

Hall & Clarke, however, recognize *S. typa* and not Hall's species as the genotype of *Syringothyris*[6]; while Weller maintains that, since the species *S. carteri* is imperfectly known, being founded upon brachial valves only (which, as is shown elsewhere in this paper, are not satisfactory criteria for discriminating between species of *Syringothyris*), and 'since it seems impossible to determine surely what *carteri* really is,' *S. typa* should still be regarded as the genotype.[7] Not having had an opportunity of examining any American material, I can only cite the conflicting opinions of the

[1] Weller [36] pp. 395–97 & pl. lxix, figs. 1–5.

[2] 'Description of Palæozoic Fossils' 10th Ann. Rep. N.Y. State Cab. Nat. Hist. 1857, p. 170.

[3] Schuchert [29] pp. 31–32.

[4] 'A Report on some of the Invertebrate Fossils of the Waverley Group and Coal-Measures of the Ohio' Rep. Geol. Surv. Ohio, vol. ii, pt. 2 (1875) p. 285.

[5] Bull. Denison Univ. vol. iii (1888) p. 41.

[6] Hall & Clarke [14] pp. 8, 48, & 50.

[7] Weller [36] p. 397.

authors mentioned, and leave the validity of the species *carteri* an open question. Fortunately, however, this does not affect the issue so far as British species are concerned, because both *Syringothyris typa* and *S. carteri* (if they are distinct forms) differ in certain respects from the holotype of *S. cuspidata*. The differences between the first and last of these have already been considered; between *carteri* and the holotype of *cuspidata* they are as follows:—

(i) In *carteri* the area is concave; in *cuspidata* flat or reclined.

(ii) In *carteri* the lateral slopes of the ventral valve are distinctly tumid; in *cuspidata* they are usually flat, or even concave.

These differences are practically the same as those which exist between the *Syringothyris* aff. *cuspidata* auctt. (for instance, the form referred to in this paper as *S. cuspidata* mut. *cyrtorhyncha*) from the *Cleistopora*- and *Zaphrentis*-Zones of the South-Western Province, and the typical *S. cuspidata* (Martin), from the Upper Avonian of Castleton (Derbyshire).

The shell described and figured by Dr. C. D. Walcott as *S. cuspidata* more closely resembles *S. carteri* than the former species.[1]

From the evidence adduced, the following conclusions may be drawn:—

(i) The genotype of *Syringothyris* is *S. typa*, Winchell, if *carteri* and *typa* are distinct, or if the former is not a valid species, which the balance of the evidence seems to favour; but, if the two names be synonymous, *carteri* takes priority as the type-species.

(ii) Both *typa* and *carteri* have much in common with the *S.* aff. *cuspidata* of the South-Western Province: therefore, in terms of the British species, the genotype belongs to that group of *Syringothyris* which is characteristic of the lower part of the Avonian, wherein the cardinal area is more or less concave and the lateral slopes of the ventral valve are tumid: and not to the true *cuspidata* group typified by Martin's holotype from the Upper Avonian.

S. cuspidata has also been regarded as the genotype of *Spirifer* Sowerby. When that genus was established by J. Sowerby in a paper read before the Linnean Society in 1814, he mentioned *Anomia striata* Martin as a typical species. That paper was, however, not published until 1819,[2] and in the meantime, in 'Mineral Conchology' vol. ii (1816) p. 43, the same author gave the species '*cuspidatus*' as an example of *Spirifer*. Thus, so far as the date of publication is concerned, the name *cuspidata* has priority, and this was the attitude adopted by King,[3] Meek,[4] and others; but Davidson has shown conclusively that Sowerby himself

[1] 'Palæontology of the Eureka District' Monogr. U.S. Geol. Surv. 8 (1884) p. 219.

[2] 'Some Account of the Spiral Tubes or Ligaments in the Genus *Terebratula* of Lamarck, as observed in several Fossil Shells' Trans. Linn. Soc. vol. xii (1819) pp. 514–16.

[3] King [16] p. 125.

[4] In F. B. Meek & F. V. Hayden, 'Palæontology of the Upper Missouri' Smiths. Contrib. Knowl. vol. xiv (1865) p. 19.

always regarded *S. striata* as the type-species of *Spirifer*[1]: and since it is now known that *cuspidata* does not belong to that genus at all, there are no reasonable grounds for disputing the claim of the former species to be regarded as the genotype of *Spirifer*.[2]

(*d*) The Subdivision of the Genus.

The species which have been referred to *Syringothyris*, and the specific names which have been applied to various forms occurring in this country are as follows:—

1. *Spirifer distans* Sowerby.
2. (*Cyrtia*) *laminosa* M'Coy.
3. (*Anomites*) *subconicus* Martin.
4. (*Anomites*) *cuspidatus* Martin.
5. (*Spirifer*) *carteri* Hall.
6. *Syringothyris typa* Winchell.
7. *Syringothyris texta* Hall.

Of these, the first three are shown in this paper to belong to other genera, while the last three are the names of American species to which certain shells from the Lower Avonian of the South-Western Province have been doubtfully referred. The use of these names is, however, undesirable, partly because of the absence of facilities for comparison with the type-specimens, and partly because American palæontologists are themselves not in agreement as to their precise significance (see p. 174). Therefore, so far as British specimens are concerned, the only valid specific name already proposed is *cuspidata*.

If isolated specimens from various horizons and different localities were considered separately, it would be comparatively easy to divide the genus into many apparently well-defined species; but, as is often the case, the greater the number of specimens examined the more difficult specific differentiation becomes. The changes dependent upon time alone are small and progressive; but, in deposits such as the Waulsortian 'knoll'-limestones, where the conditions of deposition were somewhat abnormal, the shells at any one horizon exhibit considerable variation.

The characters in which variation occurs are as follows:—

(1) The height of the area.—Generally speaking, the area increases in height from lower to higher horizons; but, as with the other characters, the greatest amount of variation is due to the existence of a special environment, and not to considerations of time (see fig. 3, p. 178).

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[1] Davidson [3] p. 81.

[2] Since these lines were written, Dr. J. Allan Thomson has cited the case of *Syringothyris cuspidata* and *Spirifer* as an example of the necessity for a list of *nomina conservanda* approved by the International Zoological Congress, so that in this and similar cases, it should not be necessary by the strict application of the law of priority to displace a name which, like *Spirifer*, has been in general use, in a well-defined sense, for a long period. See 'Brachiopod Nomenclature: *Spirifer* & *Syringothyris*' Geol. Mag. 1919, pp. 371–74; also S. S. Buckman, Geol. Mag. 1920, pp. 18–20.

(2) The curvature of the area.—Although exhibiting a fairly-wide range of variation, the nature of the area in forms from one horizon, and in rocks formed under similar conditions, is fairly constant.

In common with *Spirifer*, *Spiriferina*, and similar forms, the cardinal area is marked by numerous parallel transverse striations, which in suitably-preserved specimens are seen to be continuations of the concentric lines of growth that appear on the remainder of the surface of the shell, and therefore have a direct bearing upon the height and curvature of the area. The addition of new shelly matter in the Brachiopoda takes place at the free edges of each valve.[1]

If the deposition along the hinge-line is, throughout life, less than along the anterior margin of the shell, the area will be strongly curved, as in most species of *Spirifer*: as the marginal growth becomes more nearly uniform the area increases in height and decreases in curvature; while, when the growth along the hinge-lines is in excess, the area will be reclined, that is, convex. Usually, in the genera under consideration, the rate of growth along the hinge-line either increases or decreases progressively, during the life of the individual, so that, although in its apical portion the area is curved, it becomes practically flat towards the hinge-line.

In a general way, the curvature of the area is of taxonomic value, but it sometimes happens that in one and the same specimen the area is convex on one side of the delthyrium, and concave on the other side (see Pl. XI, fig. 7).

The area, although normally symmetrical, is sometimes distinctly twisted; but that feature depends upon differences in the curvature of the area on either side of the delthyrium.

The variations in the height of the area are, of course, accompanied by changes in the profile of the pedicle-valve, and the curvature of the floor of the sinus along a median line from the beak to the anterior margin is, especially in imperfectly-exposed specimens, a useful diagnostic character, since from it the nature of the area can be inferred (see fig. 3, p. 178).

(3) The lateral slopes.—The lateral slopes may be either flattened or tumid, and from the beak to the anterior margin may be either concave or convex according to the curvature of the area, being convex when the area is concave, and concave when the area is reclined. Excessive obesity is a gerontic condition.

(4) The costæ.—The costæ vary in size, in abundance, and in their relation to the furrows which separate them. They are sometimes nearly or quite obsolete, particularly upon the lateral slopes of the ventral valve. Obsolete costæ are usually accompanied by a reclined area.

(5) The transverse plate and syrinx.—These are useful diagnostic features. The transverse plate varies in its greatest depth beneath the plane of the cardinal area, and the syrinx varies in size relatively to the transverse plate; but, as the variations will be dealt with when certain typical forms are described, further details need not be given here (see fig. 1, p. 166).

(6) The minute surface-ornament and microscopic structure of the shell.—In the majority of specimens the intimate structure of the shell is obliterated by recrystallization, or the outer layers are lost by exfoliation, so that these features are seldom available for diagnostic purposes.

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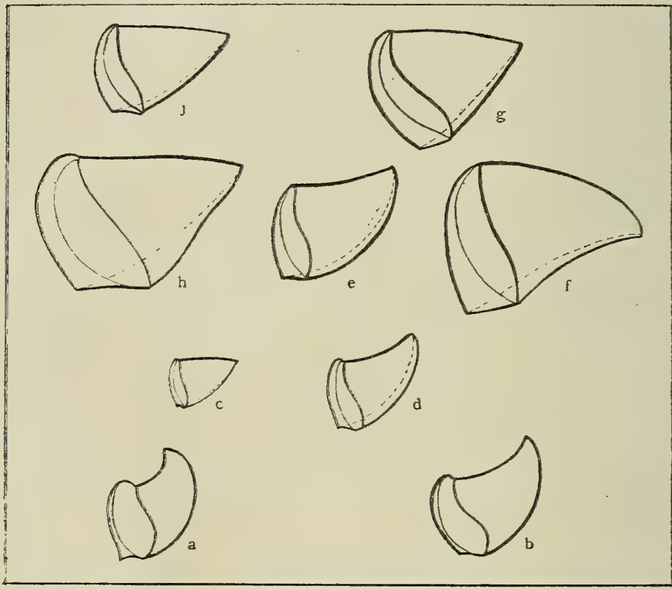
[1] J. F. van Bemmelen, 'Untersuchugen über den Anatomischen & Histologischen Bau der Brachiopoda Testicardinia,' Jenaische Zeitschr. vol. xvi (1883) p. 465. See also 'Cambridge Natural History: Mollusca & Brachiopoda,' 1895, p. 468.

It will be seen that, apart from the last-mentioned characters (6), the only variable features are, with the exception of the costæ, confined to the pedicle-valve, and there do not appear to be any other characters by which specimens showing the brachial valve only can be specifically determined.

Fig. 3.—*The profiles of* Syringothyris *and* Spirifer distans *(all half of the natural size). The broken lines represent the floor of the sinus in the pedicle-valve.*



a = *Spirifer distans*, normal type.
b = *Sp. distans*, var. *bicarinata*.
c = *Syringothyris principalis* (K).
d = *S. cuspidata*, mut. *cyrtorhyncha* (Z).
e = *S. cuspidata*, mut. *exoleta* (C), from normal deposits.
f = *S. cuspidata*, mut. *exoleta* (C), Waulsortian 'knoll'-type.
g = *S. cuspidata*, mut. *cuspidata* (D).
h = *S. elongata* (C), Waulsortian 'knoll'-type.
j = *S. elongata* (D).

(*e*) General Account of *Syringothyris* in Great Britain.

Owing to the ease and certainty with which specimens of *Syringothyris* may be generically determined, on account of the absence of plications upon the fold and the sinus, the evolution of the genus can be studied without the complications which one encounters when dealing with vaguely-defined and obviously-polyphyletic 'genera' like *Spirifer*.

In this country the genus *Syringothyris* first appears in the Lower *Cleistopora* Zone (K_1), where it is represented by forms in which all the essential characters of the genus are fully developed. No two individuals are precisely alike; but the prevailing expression is that of a small transverse shell, with a flat cardinal area of which the width is about twice the height. The transverse plate is not deeply buried, is convex upwards, and the syrinx is relatively large. This type of shell, exemplified by the form described hereafter as *Syringothyris principalis*, sp. nov. [*Syringothyris typa*, auctt.], prevails throughout the *Cleistopora* Zone, and is not found above the lowest beds of the *Zaphrentis* Zone.

Above the *Cleistopora* Zone occur two series of forms derived from *S. principalis*, and here regarded as belonging to two species: namely, *S. elongata*, sp. nov. and *S. cuspidata* (Martin). The essential difference between them lies in the greater apical angle, and the more depressed appearance of the former.

The shells referred to *S. elongata* are less numerous, and exhibit less variation than those of the other species, of which successive mutations [1] are recognized. The further history of *S. cuspidata* is as follows:—In Z_1 the prevailing type, *S. cuspidata* mut. *cyrtorhyncha* [*S. texta* auctt.], is a shell distinctly larger than *S. principalis*, and further differs from that form in that the area is slightly concave, the brachial valve less transverse, and the costæ somewhat stouter. Although, in its typical form, especially characteristic of the Lower *Zaphrentis* Subzone, forms approaching *S. cuspidata* mut. *cyrtorhyncha* occur in the underlying *Cleistopora* Zone. Owing to the lithological characters of the rocks which frequently constitute the *Zaphrentis* Zone in the South-Western Province, the shells have undergone but little recrystallization, and the minute textile ornamentation is frequently well preserved. It is on this account that they have been compared with the North American species *S. texta* (Hall).[2]

In the South-Western Province the shells found in the Upper *Zaphrentis* and *Caninia* Zones group themselves around *S. cuspidata* mut. *exoleta* [*S. carteri* auctt.], which is most abundant in and characteristic of horizon γ and the Lower *Caninia* Zone. This form differs markedly from *S. elongata*, but is less sharply differentiated from *S. cuspidata* mut. *cyrtorhyncha*.

In the North and North-West of England, *Syringothyris* has not been recorded from horizons lower than the *Caninia* Zone; but in rocks of that age it is represented by a form which in general appearance, and in its stage of development, has close affinities with *S. cuspidata* mut. *exoleta*, of which it is in all probability merely a geographical variant.

The *Caninia* Zone in the central part of Ireland, and in Belgium, is characterized by the occurrence of the remarkable Waulsortian 'knoll' facies, and in those deposits *Syringothyris* is developed in

[1] In this paper 'mutation' is used in the sense of Waagen, and not in that of De Vries.

[2] Vaughan, 'Burrington Paper' [28] p. 364.

an extraordinary manner. The shells vary within wide limits, but all agree in attaining in the adult stage an unprecedented size, accompanied in most cases by an almost complete abortion of the costæ, especially of those on the pedicle-valve. The costæ, when present, are large, but poorly defined. The increase in the size of the individual is not accompanied by any thickening of the shell-substance. Usually, the area is flat, or more or less strongly reclined; while the median line along the floor of the sinus is distinctly concave, and not convex as is the case in earlier forms, or in contemporary forms, occurring in normal deposits.

Were they not connected by intermediate forms, extreme types might well be regarded as belonging to distinct species. The variability of the shells found in the lower zones has already been mentioned, and the great diversity of form in the deposits under consideration is (in all probability) due to the accentuation of different variable characters in different individuals.

Much careful collecting will be necessary before these varied forms can be further classified, and although distinctive names, if available, would be very convenient, no useful purpose would be served by the introduction of new names until the significance of the variations is more fully understood.

In the *Seminula* Zone *Syringothyris* is rare. It is represented in the South-Western Province by forms resembling mut. *exoleta*, and in that area does not occur above that horizon. It is not known above C_2 in the North-Western Province; but in the Midlands the genus persisted until *Dibunophyllum* times, and it is there represented by *S. cuspidata* mut. *cuspidata* and *S. elongata* in D_2.

In the 'brachiopod-beds' (*Dibunophyllum* Zone) of the Midlands, and the 'reef-knolls' of the Clitheroe and Craven districts, *Syringothyris* is represented by forms which recall those found in the abnormal rock-types of the *Caninia* Zone of Ireland.

The holotype of Martin's *S. cuspidata* was obtained from beds of D_2 age at Castleton, and closely similar shells are found in the 'brachiopod-beds' at Park Hill (Derbyshire), and at Axton (Flintshire). Principal T. F. Sibly has shown that the 'brachiopod-beds' of Park Hill, Thorpe Cloud, and other localities in Derbyshire are of Middle *Dibunophyllum* age (D_2, subzone of *Lonsdalia floriformis*), and Dr. H. H. Bemrose's observations on the toadstones of Derbyshire indicate that the shell-beds of Castleton are of similar age.

The age of the knolls at Cracoe and Clitheroe is less certain: Vaughan in his last paper [1] expressed the opinion that they were, in part at least, considerably older than the 'brachiopod-beds,' and included representatives of the *Seminula* Zone, and perhaps of the *Caninia* Zone also.

It is not intended to discuss in detail the relative ages of the Upper Avonian 'brachiopod-beds' and 'reef-knolls'; but it is

[1] Vaughan, 'Dinant Paper' [35] p. 15.

interesting to record in this connexion that the examples of *Syringothyris* from the Cracoe knolls much more closely resemble those from the Irish Waulsortian knoll-phase limestones, than those from the Derbyshire 'brachiopod-beds.' Nevertheless, the special characters of the specimens from the Waulsortian knolls and the 'brachiopod-beds' are dependent upon the existence of special conditions rather than upon the time at which these conditions occur, and it is not safe to base conclusions as to the age of the rocks upon forms of *Syringothyris* alone.

Shells exactly resembling the Castleton type occur at Little Island (Cork), in beds which, in age, probably correspond closely with those at Castleton. In the list of fossils from the Carboniferous Limestone from the vicinity of Cork given in 'The Geology of the Country around Cork & Cork Harbour,'[1] the fossils from all horizons are tabulated together; but some of them suggest the presence of beds of *Dibunophyllum* age, and several of the fossils enumerated are characteristic of the Middle and Upper *Dibunophyllum* Subzones in the Midlands. In common with most of the fossils from the neighbourhood, the specimens of *S. cuspidata* are curiously distorted by pressure; but their similarity to the Castleton shells is very apparent (see Pl. XII, figs. 2 *a* & 2 *b*).

The genus has not yet been found anywhere in rocks later in age than the *Dibunophyllum* Zone.

Summary of Notes on the Distribution of *Syringothyris*.

From this account of the distribution of *Syringothyris*, it appears that in the South-Western Province, where there was no marked alteration in the conditions of deposition from *Cleistopora* to Lower *Caninia* times, the changes in the genus were continuous and progressive. In common with many other brachiopod genera, it disappeared from that area after the commencement of the special conditions which prevailed immediately before and during *Seminula* times, and never reappeared there. In other areas, factors such as migration and the occurrence of abnormal conditions of deposition render the sequence less clear.

In Ireland, the genus becomes increasingly important from the *Cleistopora* Zone, where it is very rare, to the *Caninia* Zone, and is seldom met with at higher horizons. In the Midlands and North of England it is not present in the lowest beds of Carboniferous Limestone, but appears in the *Caninia* Zone in the North, and in the *Dibunophyllum* Zone in the Midlands. Here, as in Ireland, for reasons which have already been given, variations due to time alone cannot definitely be distinguished.

The genus illustrates in an interesting way some of the principles of evolution. The (phylogenetically) young stage with small and

[1] Mem. Geol. Surv. 1905, pp. 29–31.

simple forms is represented by the earlier mutations of both *cuspidata* and *elongata*: the adult stage, in which the full size is attained and all the characters are mature, is seen in the mut. *exoleta* and in the *Caninia*-Zone representatives of *S. elongata*; while phylogenetic old age with 'exaggeration and per-elaboration,' followed quickly by extinction,[1] was reached (in normal limestone-deposits) in the *Dibunophyllum* Zone, but was, in certain areas, hastened by the special conditions accompanying the formation of the 'reef-knolls.'

(*f*) Description of the British Species of *Syringothyris* and their Mutations.

SYRINGOTHYRIS PRINCIPALIS, sp. nov. (Text-figs. 1 *a*–1 *c*, 3 *c*, pp. 166, 178; Pl. XI, figs. 1 & 2.)

1905. *Syringothyris* aff. *cuspidata* (Martin)—Vaughan [33] p. 215.
1911. *Syringothris typa* Winchell, Hall —Vaughan [28] p. 364.
1913. *Syringothyris* aff. *carteri*—North [25] p. 401.
1917. *Syringothyris* cf. *cuspidata*—Dixey & Sibly [6] p. 131.

In this species the shell is smaller than in any later representatives of the genus: the dimensions of an average specimen being—width along the hinge-line, 35 mm.; length of brachial valve, 16 mm.; height of area, 15 mm.

Description:—Pedicle-valve.—Area practically flat, apical angle about 100°. Sinus wide, shallow, and not sharply defined by the costæ on either side of it: a median line along its floor is almost flat, except near the apex where it is slightly curved. Lateral slopes more or less flattened. Costæ fine, but distinct right up to the apex, and frequently somewhat sinuous; they are rounded but very depressed, and are separated by narrow groove-like furrows; there are about eighteen or twenty on each lateral slope. Delthyrial supporting-plates markedly divergent; syrinx relatively large, but not deeply buried beneath the level of the area (see text-fig. 1 *b*, p. 166). The delthyrial supporting-plates fail to extend completely across the valve in transverse sections where the syrinx is most typically developed.

Brachial valve.—There are few distinctive features in this valve. The fold is sharply defined and evenly convex, but not much raised above the general level of the valve: lateral slopes flattened towards the cardinal extremities. The costæ resemble those in the opposite valve, but are not sinuous. The beak is inconspicuous, and but little raised above the hinge-line.

Holotype.—A pedicle-valve from K_2 subzone, Howle Hill, near Ross (Herefordshire), in the collection of Principal T. F. Sibly (Pl. XI, fig. 2).

Horizon and localities.—This species is especially characteristic of the *Cleistopora* Zone, but extends into, and is rarely represented in the lowest beds of, the succeeding horizon; it is

[1] Vaughan [35] p. 3.

almost confined to the South-Western Province. It is represented by fragmentary specimens recorded by Vaughan from Km in the Bristol area, and reaches its acme in that district in K_1, and in the Burrington Section and in the east of Glamorgan, in K_2. Other localities are: Coed yr Gang, Upper Neath Valley, K_1[1]; Mitcheldean district (Gloucestershire), K_2.

Syringothyris is said to be very rare in K in Ireland.[2]

Remarks.—The flat area serves to distinguish this species from *S. cuspidata* mut. *cyrtorhyncha*; and its small size, and slender but sharply-defined costæ enable it to be distinguished from those forms which occur at higher horizons.

SYRINGOTHYRIS ELONGATA, sp. nov. (Text-figs. 1 *e*, 1 *f*, 3 *h*, & 3 *j*, pp. 166, 178; Pl. XII, figs. 3–5.)

Description:—Pedicle-valve.—Area flat, and about twice as wide as high, apical angle about 100°, beak sharp: sinus wide and well defined, the median line along its floor slightly convex. Costæ distinct, flattened and separated by narrow furrows; about eighteen or twenty on each lateral slope, those nearest the sinus are about 2 mm. wide at the anterior margin: lateral slopes more or less flattened and falling away sharply from the plane of the area. Delthyrial supporting-plates subparallel; transverse plates not deeply submerged; syrinx relatively large. (See text-figs. 1 *e* & 1 *f*.)

Brachial valve more than twice as wide as long, cardinal extremities subangular or slightly produced: costæ as in the opposite valve, but more clearly defined: fold wide and depressed, but distinctly raised above the general level of the valve.

The dimensions of an average specimen are as follows:—width along hinge-line, 66 mm.; length of brachial valve, 24 mm.; height of area, 28 mm.

Remarks.—This species resembles in general appearance *S. principalis* from the *Cleistopora* Zone, but differs from it in its size, and in the small angle of divergence of its delthyrial supporting-plates, which are relatively longer, and extend completely across the cavity in sections where the syrinx has nearly disappeared, while in *S. principalis* they are already incomplete in sections where the syrinx is best developed. From *S. cuspidata* it differs in its greater relative width, larger apical angle, and its subangular cardinal extremities.

Holotype.—A specimen in the collection of the Geological Survey of Ireland (Reg. No. 1492); horizon, *Caninia* Zone; locality, south of Adare (Limerick). (Pl. XII, figs. 4 *a*–4 *c*.)

Horizons and localities.—This species is represented in rocks of both Lower and Upper Avonian age; and, while examples from different horizons present small variations, they are similar in general characters, nor can they at present be satisfactorily differentiated. It is recorded from Z to C in Ireland: for instance,

[1] Collected by the late Mr. C. H. Cunnington.
[2] Douglas [8] p. 548.

Z, Malahide; C, Adare (Limerick) and Rathfeale (Cork); and from the *Dibunophyllum* Zone in the Midlands and Yorkshire (as, for example, Coniston Cold, Skipton[1] D_2, Kniveton).

As in the case of *S. cuspidata*, this species attains its maximum size in the Waulsortian 'knoll'-limestones of Ireland.

SYRINGOTHYRIS CUSPIDATA (Martin).

In this species are included shells from Z to D inclusive, in which the brachial valve is about twice as wide as high, apical angle about 90° to 100° (100° in the earlier, and 90° in the later mutations), cardinal extremities rounded. Mutations characteristic of various horizons are recognized, together with variations due to geographical distribution and to environmental conditions.

SYRINGOTHYRIS CUSPIDATA mut. CYRTORHYNCHA. (Text-fig. 3 *d*, p. 178; Pl. XI, figs. 3 *a* & 3 *b*.)

1825. *Spirifer cuspidatus* (Martin)—Sowerby [32] p. 90 & pl. cccclxi, figs. 1–2.
1911. *Syringothyris* cf. *texta* Hall—Vaughan, 'Burrington Paper' [28] p. 365.

Description:—Pedicle-valve.—Area flattened near the hinge-line, but concave towards the beak, which is pointed; apical angle about 100°: sinus wide, evenly concave from side to side, and convex from the beak to the anterior margin. Costæ about twenty on each lateral slope, low and rounded, and separated by narrow furrows; lateral slopes tumid, and making an obtuse angle with the cardinal area. Delthyrial supporting-plates stout, divergent, but less so than in *S. principalis*; syrinx relatively large, not deeply buried.

Brachial valve evenly convex; fold distinct and rounded; cardinal extremities almost right-angles; beak small, and but little raised above the level of the area.

The dimensions of an average specimen are as follows:—width along hinge-line, 40 mm.; length of brachial valve, 22 mm.; height of area, 17 mm.

Owing to the lithological characters of the rocks (of the *Zaphrentis* Zone) in which this mutation occurs in the South-Western Province, the surface of well-preserved specimens shows the characteristic minute ornament, resembling twilled cloth.

Example.—A specimen from the Avon Section, Bristol (Z), in my collection, and now deposited in the National Museum of Wales (Reg. No. 19246 G 2). (Figured in Pl. XI, figs. 3 *a* & 3 *b*.)

Horizons and localities.—The *Zaphrentis* Zone in the South-Western Province and in Ireland. In the lowest beds of the zone some of the shells are more or less intermediate between this mutation of *S. cuspidata* and *S. principalis*, and towards the top of the zone the mutation gives place to *S. cuspidata* mut. *exoleta*.

[1] Specimen in the British Museum (Natural History) Reg. No. B 20247.

Remarks.—This mutation of *S. cuspidata* is readily distinguished from *S. principalis* by its curved area. It is smaller than *S. cuspidata* mut. *exoleta*, but has all the essential characters of that mutation developed in a minor degree.

Syringothyris cuspidata mut. exoleta. (Text-figs. 1 *d*, 3 *e* & 3 *f*, pp. 166, 178; Pl. XI, figs. 4 *a*–5 *b*.)

1858. *Spirifera cuspidata* Martin sp.—Davidson [4] p. 44 & pl. viii, figs. 19–20.
1917. *Syringothyris* cf. *cuspidata* (Martin)—Dixey & Sibly [6] p. 142.

In general characters, examples of this mutation from normal limestone-deposits are intermediate between the mutation *cyrtorhyncha* already described and the typical mutation *cuspidata*.

In *S. cuspidata* mut. *exoleta* the genus *Syringothyris* reached, in the British-Belgian area, its acme in the size and number of individuals and in geographical distribution.

Description (of the normal type characteristic of the South-Western Province):—Pedicle-valve.—Area concave, especially towards the beak; apical angle about 100°; sinus wide and shallow, the median line along its floor being evenly and markedly convex. Costæ well defined anteriorly, rounded, but depressed, and separated by narrow furrows; lateral slopes rounded and tumid. Delthyrial supporting-plates slightly divergent; syrinx well developed and relatively large.

Brachial valve.—A little more than twice as wide as long, convex, fold well defined, low, and rounded; beak slightly inflated and raised above the level of the area, but less so than in the later forms.

Typical examples.—Specimens from Weston-super-Mare and from Sutton, Glamorgan (see Pl. XI, figs. 4 *a* & 4 *b*), in the collection of Principal T. F. Sibly.

Horizons and localities.—In the South-Western Province this mutation ranges from Z_2 to C, and has also been recorded as occurring rarely in S_1. It does not everywhere attain its maximum at the same horizon, but reaches its acme in the Bristol district in Z_2, in East Glamorgan at horizon γ, and in the Mendip area in C_1. Normal examples of this mutation occur in the *Caninia* Zone in Ireland.

Variations of mut. *exoleta*.

It has already been stated that this mutation is typically developed in the South-Western Province. In the North-West of England it is represented by forms which have all the essential characters of the mutation, but are somewhat less tumid, and in which the flattening of the ribs is more apparent and the beak of the pedicle-valve sharper. This type has been recorded by Prof. E. J. Garwood in the Brownber Pebble-Beds (sub-zone of *Seminula gregaria*, lower part of C_2),[1] and in a hard calcareous

[1] Garwood [13] p. 464.

grit of similar age at Kendal.[1] Davidson figured it from Kendal.[2] The difference between these northern representatives of mut. *exoleta* and those from the South-Western Province is probably, in part at least, explained by the fact that in the former area they occur almost exclusively in oolitic and arenaceous deposits, while in the latter they are usually found in the crinoidal and shelly limestones.

The peculiar variations of mut. *exoleta* found in the Waulsortian knolls of Ireland have already been referred to.

SYRINGOTHYRIS CUSPIDATA mut. CUSPIDATA. (Text-fig. 3*g*, p. 178; Pl. XI, figs. 7–8 & Pl. XII, figs. 1 *a*–2 *b*.)

1796. *Anomites cuspidatus* Martin [22] p. 44 & pl. iii, figs. 1–4.
1809. *Conchyliolithus anomites cuspidatus* Martin [23] pl. xlvi, figs. 3–4 & pl. xlvii, fig. 5.
1816. *Spirifer cuspidatus* J. de C. Sowerby [32] pl. cxx, fig. 3.
1836. *Spirifera cuspidata* Phillips [27] p. 216 & pl. ix, fig. 1.
1858. *Spirifera cuspidata* Davidson [4] pl. viii, figs. 21–24 & pl. ix, fig. 2.
1868. *Spirifera cuspidata* King [17] pls. ii–iii.

This is the typical form of *S. cuspidata* represented by Martin's holotype. Its distinguishing features are as follows:—Apical angle about 90°, area rather more than half as high as wide, nearly flat, but slightly reclined, and rounding over into the somewhat inflated lateral slopes; cardinal extremities rounded. Brachial valve strongly convex, with a swollen beak well raised above the level of the hinge-line. Costæ about sixteen on each lateral slope, strong, depressed, separated by furrows wider and less numerous than those in the earlier forms of *S. cuspidata* and in contemporary examples of *S. elongata*. Delthyrial supporting-plates nearly parallel; transverse plate thin; syrinx perfectly developed, but relatively small.

The dimensions of an average specimen are as follows:—width along hinge-line, 56 mm.; length of brachial valve, 30 mm.; height of area, 32 mm. Very rarely the mutation is represented by giant specimens measuring nearly 100 mm. in width.

Horizon and localities.—This mutation occurs only in the *Dibunophyllum* Zone, especially D_2, and is represented in the Midlands, in Yorkshire, and at Axton (Flintshire); and by the distorted specimens from Cork, already mentioned on p. 181.

(*g*) Pre-Carboniferous History of *Syringothyris*.

In this country and in Belgium, *Syringothyris* first appears in the *Cleistopora* Zone of the Carboniferous Limestone, with all its essential characters fully developed; but in neither of those areas do the Devonian rocks yield any Spiriferid shells that can be regarded as possible ancestors of *Syringothyris*.

An apical callosity and even a transverse plate are frequently

[1] A number of specimens are in the Sedgwick Museum, Tablet 639.

[2] Davidson's figures [4] pl. lii, figs. 3 & 3 *a*, appear to be idealized, and to combine the characters of *S. cuspidata* and *Tylothyris subconica*.

developed in certain species of *Spirifer* from both Devonian and Carboniferous rocks, for instance: *Sp. disjunctus* J. de C. Sowerby, *Sp. duplicicosta* Phillips, and *Sp. striatus* (Martin); and if, as unfortunately is seldom the case, a specimen is suitably preserved and its internal structures are not obliterated by recrystallization, the transverse plate can be seen when the beak of the ventral valve is rubbed away. Text-figs. 1*i* & 1*j* (p. 166) represent the structure as observed in a specimen of *Sp. duplicicosta* from Park Hill (Derbyshire), the sections being 3 and 6 mm. from the beak respectively. In text-fig. 1*i* (p. 166) the structure is seen to be essentially the same as in the apical region of *Syringothyris*.

In text-fig. 1*j*, although the relation between the transverse plate and the delthyrial supporting-plates is the same as in *Syringothyris* (see text-fig. 1*d*), there is no trace of a syrinx. The extremity of the plate is concave, as in *Syringothyris*; and therefore, in sections farther from the beak than text-fig. 1*j*, it is incomplete, being represented by two small portions on the inner sides of the delthyrial supporting-plates. A similar transverse plate was observed by me in a large specimen of *Sp. striatus* (Martin) from Kildare; King describes a section showing the transverse plate in this species,[1] in which he supposed that there was actually a tubular canal, but this has not been verified; in any case, the structure figured by King bears no resemblance to a true syrinx.

It has already been shown that the species in which a syrinx is known to exist have a smooth fold and sinus, and the examination of the forms just considered proves that it is not present in species in which the fold and sinus are plicated (this matter is more fully discussed in § III of this paper, p. 189). The whole of the evidence, therefore, points to the conclusion that it is among species of the former type that the ancestors of *Syringothyris* must be sought.

In the Devonian rocks of North America there seems to be clear evidence of the evolution of the syrinx. American palæontologists have described a number of species of *Spirifer* in which the fold and sinus are non-plicate, and in which a well-developed apical callosity and transverse plate are seen: as, for example, *Sp. granulosus* Conrad and *Sp. asper* Hall, both from the Hamilton group (Middle Devonian). In many specimens the plate is said to be more or less thickened along the median line. In a variety of *Sp. marcyi* Hall from the Upper Devonian of New York, described by H. S. Williams,[2] there are two parallel ridges on the under surface of the transverse plate, and that author regards the structure as an incipient syrinx.

If text-fig. 1*g* (p. 166), which is a cross-section of the beak of *Sp. marcyi*, be compared with fig. 1*h*, which illustrates the fully-developed syrinx of *Syringothyris*, the relation between the two forms is at once apparent.

[1] King [17] pl. iii, fig. 25.
[2] Williams [37] pp. 61–62 & fig. 16.

In the absence of specimens and accurate stratigraphical evidence a detailed discussion of this interesting subject is not possible, and the following summary of the evolution of *Syringothyris* is to a great extent based upon the descriptions given by James Hall & J. M. Clarke,[1] G. H. Girty,[2] and H. S. Williams.[3]

In many Lower Devonian Spirifers there was, as the organism reached maturity, a tendency to deposit shelly matter (an apical callosity) in the beak of the pedicle-valve. From the free, that is, dorsally-directed, end of that callosity, a plate (the transverse plate) extended forward between the delthyrial supporting-plates, anterior to, or below, the deltidium. Originally an accompaniment of mature growth, these characters seem eventually to have become permanent, and in late Devonian and Carboniferous times were essential features in many species.

In some forms, in which the radial ornament extended over the whole shell, the plate remained unchanged, while in others, characterized by a smooth fold and sinus, it became curiously modified.[4] A pair of longitudinal ridges were developed on the nether surface of the plate, and these, in the course of time, gave rise to two lamellæ, the free ends of which curled one towards the other to form an incomplete tube or syrinx. The formation of the syrinx was preceded and accompanied by a flattening and great elevation of the cardinal area of the valve.

A departure from the usual conditions is seen in the species described by Weller as *Pseudosyrinx sampsoni*.

Pseudosyrinx Weller.

'The Mississippian Brachiopoda of the Mississippi Valley Basin' Illinois Geol. Surv. Monogr. 1 (1914) pp. 404–405.

The forms referred to this genus resemble *Syringothyris* in all respects save one: namely, the nature of the transverse plate. In shape and size, in the absence of plications on the fold and sinus, in the differentiation of the area into a central and two lateral portions (of which only the former is marked by vertical striations), and in the punctation of the shell-substance, *Pseudosyrinx* agrees with *Syringothyris*; but the transverse plate is quite simple, and bears no trace whatever of the existence of a syrinx. The possibility that the absence of the syrinx might be due to the mode of preservation of the shell was carefully considered by the author of the genus, who found that the feature was of constant occurrence in specimens preserved in such a way as to show with certainty that no syrinx had ever existed.

Pseudosyrinx is found in the Lower Mississippian of North America: that is, it was contemporaneous with *Syringothyris*; and the coexistence of forms, externally indistinguishable, the

[1] Hall & Clarke [14]. [2] Girty [12] p. 51.

[3] Williams [37] pp. 61–62.

[4] These two types practically coincide with two of the groups into which the Spirifers were divided by Hall & Clarke: namely, the 'aperturati' and the 'ostiolati' respectively.

majority of which possessed a syrinx while a few did not, is somewhat remarkable.

So far as I am aware, no shells referable to the genus have been found in the Carboniferous Limestone of Great Britain and Ireland.

Type-species.—*Pseudosyrinx sampsoni* (Weller). Illinois Geol. Surv. Monogr. 1 (1914) pp. 405–406 & pl. lxvii, figs. 11–13; *Syringothyris sampsoni* Weller, Bull. Geol. Soc. Am. vol. xx (1909) p. 311 & pl. xiv, fig. 4.

The prevailing septal arrangement in the pedicle-valve of forms with a plicated fold and sinus is that described as existing in *Sp. duplicicosta* (see fig. 1 *i*, p. 166), but E. M. Kindle has described a curious modification of the septa in certain Devonian fossils, for which he established the genus *Syringospira*.

Syringospira Kindle.

'The Devonian Fauna of the Ouray Limestone' Bull. U.S. Geol. Surv. 391 (1909) pp. 28–29.

The genus was established for shells in which the pedicle-valve is pyramidal and the area flat, as in *S. cuspidata*. The author in describing the genus says: 'though somewhat closely related to *Syringothyris*, it represents a type generically distinct from it'; actually, however, it resembles *Syringothyris* in nothing but its pyramidal shape.

Type-species.—*S. prima* Kindle, *op. cit.* pp. 29–30 & pl. vii, figs. 8–8 *d*; pl. viii, figs. 1–1 *a*. This is the only species at present referred to the genus, and only two specimens were known to the author when the name was proposed.

Horizon and locality.—The (Devonian) Ouray Limestone, Hillsboro' (New Mexico).

S. prima differs from *Syringothyris* in the following respects:—

(1) The whole surface of the shell, including the fold and sinus, is plicated, and the ribs are much more numerous than in any species of *Syringothyris*.

(2) The septal system in the pedicle-valve consists of a small transverse plate joining the delthyrial supporting-plates a little below the level of the area. The delthyrial supporting-plates do not extend to the floor of the valve, but curve towards one another and unite in the median line (see fig. ~~1e~~, p. 166). / l

(3) The shell-substance is impunctate, and the whole area is marked by vertical striations.

III. Notes upon Certain Species incorrectly referred to *Syringothyris*, and upon Species of *Syringothyris* supposed to possess Plications upon the Fold and Sinus.—The Genus *Syringopleura*.

Spirifer distans Sowerby, a species in which costæ occur on the fold and sinus as well as on the lateral slopes of the shell, has been referred to *Syringothyris*; *Spirifer altus* Hall (Middle Devonian), with similar external characters, has been regarded as

an ancestor of *Syringothyris*; and '*Spirifer*' *randalli* Simpson was stated by Simpson to have a syrinx in a shell the fold and sinus of which were plicated; but in none of these cases has the coexistence of the external characters mentioned, with a transverse plate and syrinx, been proved.

SYRINGOTHYRIS RANDALLI (Simpson).

1890. *Spirifer randalli* Simpson, Trans. Amer. Phil. Soc. vol. xvi, p. 441.
1910. *Syringopleura randalli* Schuchert, Amer. Journ. Sci. ser. 4, vol. xxx, pp. 223–24.

Horizon and locality of the type-specimens.—A little below the Sub-Olean Conglomerate, that is, fairly high in the American equivalent of the Carboniferous Limestone, at Warren, Philadelphia.

In 1910 Schuchert established a genus *Syringopleura* to include syrinx-bearing Spiriferid shells, in which there were costæ on the fold and sinus, and his genotype was *Spirifer randalli* Simpson.

Girty,[1] however, rejects that genus on the following grounds:—*S. randalli* was not correctly described by Simpson, who, owing to the imperfection of his material, apparently confused two forms which occur together in the same formation, and he attributed to the Syringothyroid species *randalli* the external characters of a true *Spirifer*. Simpson described his species as being externally like *Sp. disjunctus*, with from forty to sixty radial costæ, which at once suggests that the specimen upon which that statement was founded could not have been a *Syringothyris*, in which the number of costæ is between twenty and thirty. Girty maintains that of Simpson's original specimens those which possess a transverse plate and syrinx have a smooth fold and sinus. If this is the case, the species is correctly regarded as a *Syringothyris*, and has a smooth fold and sinus.

SPIRIFER ALTUS Hall.

1836. *Spirifer alta* Hall. Proc. Am. Phil. Soc. vol. x, pp. 246–54, see also 'Pal. New York' vol. iv (1867) p. 248 & pl. xliii, figs. 1–7.
1894. *Cyrtia alta* Hall & Clarke, 'Pal. New York' vol. viii, pt. 2, p. 42.

This is a Middle Devonian form possessing a high area and a transverse plate, and was regarded by Hall as a direct ancestor of *Syringothyris*. There is, however, no trace of a syrinx, but only a median thickening of the transverse plate, and the fold and sinus are plicated. Hall compared his species with *Spirifer simplex* Phillips,[2] but in that form the shell is smooth.

[1] Girty [11] pp. 548–54.

[2] J. A. Phillips, 'Figures & Descriptions of the Palæozoic Fossils of Devon, Cornwall, & West Somerset' 1841, p. 71 & pl. xxix, fig. 124. I have examined several specimens of *Sp. simplex* from the Middle Devonian of Devon, but have not obtained any evidence of the existence of a transverse plate.

The existence of a transverse plate in a Devonian *Spirifer* does not of necessity indicate an ancestor of *Syringothyris*; for, as is shown elsewhere in this paper, such a structure occurs in a number of species of *Spirifer*, and, furthermore, the plicated fold and sinus clearly indicate that the species under consideration has no connexion with Winchell's.

SPIRIFER DISTANS J. de C. Sowerby.

1825. *Spirifer distans* J. de C. Sowerby [32] p. 152 & pl. ccccxciv, fig. 3 (two figures).
1844. *Cyrtia distans* Sowerby, M'Coy [20] p. 136.
1858. *Spirifer distans* Sowerby, Davidson [4] pl. viii, figs. 1–16.
1880. *Syringothyris distans* Sowerby sp., Davidson [5] p. 281 & pl. xxxiii, figs. 4–5.

The fossils which have been described under this name seem to include more than one species, and they have been regarded as *Syringothyris*, although none of them really belong to that genus.

They all agree in having more or less clearly-defined plications on the fold and sinus, a character which in itself is sufficient to suggest that they are not species of *Syringothyris*.

The locality of the holotype of the species is recorded by Sowerby as 'Dublin,' and although it has also been noticed in other parts of Ireland, there do not appear to be any forms in the Carboniferous Limestone of England and Wales that can be definitely referred to this species.

Spirifer distans exhibits considerable variation in the length of the hinge-line. Some specimens, as, for instance, Sowerby's holotype, closely resemble a normal Spirifer, but other examples have a relatively longer hinge-line and a less incurved area.

Sp. distans differs from *Syringothyris* in many respects. In general appearance the shell bears a much closer resemblance to *Spirifer*. The lateral slopes of each valve are more tumid, and the area is less elevated and more incurved than in *Syringothyris*. (This more especially applies to forms like Sowerby's holotype, because in the height and curvature of the area some examples resemble the form of *Syringothyris* found in the *Zaphrentis* Zone of the South-Western Province.) The apical angle of *Sp. distans* is greater, from 120° to 125°, as against 95° to 105° in *S. cuspidata*; the delthyrial fissure is proportionately narrower, its sides diverging at an angle of about 16°, while in *Syringothyris* the corresponding angle is about 25°. The delthyrial supporting-plates are situated almost at right angles to the plane of the cardinal area, and in consequence of the narrow fissure appear in sections across the beak of the ventral valve as a pair of nearly parallel plates, much closer together than is the case with *Syringothyris* (see fig. 1 *k*, p. 166). There is in *Sp. distans* no threefold division of the area, which is marked by vertical striations throughout its entire length.

The fold is very little elevated, and makes a much less pronounced wave in the anterior margin than in *Syringothyris*. The costæ,

especially those near the fold, show a tendency to bifurcation. a condition not found in any shell in which Syringothyroid characters have been proved to exist.

The fold is divided by a shallow median depression into two broad, low, rounded costæ, and the depression itself may or may not be slightly undulated. The sinus is marked by about eight costæ, quite distinct, but not so well developed as those on the lateral slopes of the shell.

I have not succeeded in obtaining any evidence of the existence of punctations in the shell-structure; but, for reasons which have already been given, that does not necessarily prove their absence, since all the specimens were either recrystallized, silicified. or partly exfoliated.

The elongate type of *Spirifer distans* is strongly suggestive of the shell described by M'Coy as *Sp. bicarinata*,[1] but his single figure inadequately represents it. Subsequently, however, Davidson re-figured the original specimen in another position. and his illustration,[2] together with M'Coy's description, leaves little doubt as to the identity of the specimen. As already mentioned, the normal and the elongate types are connected by intermediate forms, and there are no grounds for regarding them as distinct species; but the name *bicarinata* may conveniently be used as a varietal name to designate specimens of the latter type. The significance of the two names would then be as follows:—

(1) *Sp. distans* Sowerby (text-fig. 3 *a*, p. 178).
Shell ovoid, about or rather less than twice as long as wide; cardinal extremities rounded. Example: Sowerby, 'Mineral Conchology' pl. ccccxciv, fig. 3; and Davidson [4] pl. viii, figs. 1–4.

(2) *Sp. distans*, var. *bicarinata* M'Coy (text-fig. 3 *b*, p. 178).
Shell distinctly elongated; greatest diameter at the hinge-line; more than twice as long as wide; cardinal extremities angular and produced. In the specimen figured by M'Coy the fold in the brachial valve is slightly concave, but this is only one aspect of the irregularly-plicated fold of the species, and has no taxonomic value.
Example: M'Coy [20] p. 129 & pl. xxii, fig. 10; Davidson [4] pl. viii, figs. 11–14, 16 & 18, pl. lii, fig. 5.

There does not appear to be any record of the occurrence of a transverse plate and syrinx in a correctly-determined specimen of *Sp. distans*, and in the specimens which have been rubbed down in the course of this investigation no trace of any such structure has been observed, although the delthyrial supporting-plates were perfectly preserved. This seems sufficient reason for asserting that no syrinx-bearing plate occurs, and, therefore, that the species does not belong to *Syringothyris*, but must be referred to *Spirifer*.

De Koninck's discovery of the syrinx has already been mentioned, and it has been shown that the structure which he described was exactly like that of *Syringothyris*; it now remains

[1] M'Coy [20] p. 129 & pl. xxii, fig. 10; see also Davidson [4] pl. viii. fig. 18, where M'Coy's figure is reproduced.

[2] Davidson, *op. cit.* p. 224 & pl. lii, fig. 5.

to see whether his specimen was correctly named. His figures[1] certainly do not indicate anything like Sowerby's holotype of *Spirifer distans*. One of them (fig. 5) shows a threefold division of the area, and a delthyrium relatively wider than that of *Sp. distans*, while fig. 6 is obviously a *Syringothyris*. Neither of the figures is sufficiently clear to admit of specific determination; but they most probably represent one of the Lower Avonian forms of *Syringothyris*.

There can, therefore, be no doubt that the possession of a non-plicate fold and sinus is an essential feature of *Syringothyris*. So far as I am aware, the three species enumerated in this section are the only species that are supposed not to conform with this rule, but in no case does the supposition hold good. It was necessary to establish this fact clearly, because it has an important bearing upon the phylogeny of the genus, in that it limits the stock to a group of Spirifers with a smooth fold and sinus: that is, a group corresponding approximately to the 'ostiolati' of Hall & Clarke; for, although a high area in the pedicle-valve may be developed in several members of the Spiriferidæ (as, for example, *Cyrtia*, *Spirifer*, etc.), it is only in forms with a smooth fold and sinus that the feature is accompanied by the formation of a syrinx-bearing transverse plate.

In his description of *Sp. distans*, Davidson says that the fold on the brachial valve may extend to the front margin, as in the typical form, or may soon become converted into a central rib.[2]

There is, in the Carboniferous Limestone of Derbyshire and Lancashire, a well-defined form which possesses the last-mentioned character, and it has usually been referred to *Sp. distans*. In general appearance: that is, in the height and curvature of the area, magnitude of the apical angle, width of the delthyrium, and tumidity of the lateral slopes, it closely resembles the elongate type of that species; the peculiarity of the fold and sinus, however, is so striking that the form is best regarded as a distinct species, and it is described below as *Spirifer plicatosulcatus*, sp. nov.

The presence of a median costa on the fold and sinus recalls *Sp. triangularis* (Martin); but the two species are totally different in all other respects.

Spirifer plicatosulcatus, sp. nov. (Pl. XIII, figs. 17 *a* & 17 *b*.)

Description.—Shell transversely trigonal, greatest width along the hinge-line, cardinal extremities acutely angular. The dimensions of the holotype are:—width along hinge-line, 64 mm.; length of brachial valve, 23 mm.; height of area, 21 mm.

Pedicle-valve sub-pyramidal, cardinal angles sharp, and lateral slopes evenly convex. Cardinal area nearly flat in the neighbourhood of the hinge-line, but becoming increasingly convex towards

[1] De Koninck [18] pl. ii, figs. 5 & 6. [2] Davidson [4] p. 46.

the beak, which is small, pointed, slightly incurved, and situated well above a line perpendicular to the plane of the brachial valve. Width of the area at the hinge-line rather more than three times its height, apical angle about 130°; delthyrium narrow, its width at the base being one-third of its height, delthyrial angle about 18°. Sinus shallow, with a median angular costa in the anterior half, corresponding to the costa on the fold in the opposite valve. The sinus is produced anteriorly into a quadrate tongue-like projection; a line along the bottom of the sinus from the beak to the anterior margin is evenly curved, and is practically a quarter of a circle.

Brachial valve convex, the greatest convexity being between the middle line and the anterior margin; mesial fold distinct, but not much raised above the general level of the valve, except towards the anterior margin. The mesial fold is divided by a shallow median depression, increasing in width from the beak to the margin of the valve, and on the floor of which in its anterior half there is a pronounced subangular costa.

Each lateral slope in both valves bears nineteen or twenty low rounded costæ, usually simple, but occasionally bifurcating and decreasing gradually in size as they approach the cardinal extremities.

Shell-structure unknown; in none of the specimens examined was the shell-substance sufficiently well-preserved to admit of microscopic examination.

Internally the delthyrial supporting-plates are perpendicular to the plane of the cardinal area, and in cross-sections near to the beak they appear as a pair of close parallel plates not connected by a transverse plate. There is no median septum in the pedicle-valve.

Horizon and localities.—This species occurs in the *Dibunophyllum* Zone, D_2–D_3, 'Brachiopod-Beds.' The locality of the holotype is Beeston, near Waterhouses (Staffordshire); it is also represented by smaller specimens at Park Hill and Castleton (Derbyshire).

The holotype is in the Museum of Practical Geology, Jermyn Street, London, and is numbered 28422.

IV. 'Spiriferina' laminosa (M'Coy): Tylothyris, gen. nov.

The species *Sp. laminosa* M'Coy has given rise to considerable discussion. It has at various times been referred to at least four genera, in addition to the one to which it is assigned in this paper, and in it have been included forms which, although slightly resembling it in external characters, really belong to other genera.

The uncertainty in the use of the name is to be attributed to two circumstances: (1) M'Coy's original description is inadequate, and his figures are too crude to portray clearly the characters of the species, while the holotype, which was originally in the Griffith

Collection, is no longer in existence, or at least cannot be recognized [1]; (2) The various ways in which the fossils have been preserved make their identification a matter of considerable difficulty. Many specimens are silicified, and show only the external appearance of the shell; others are more or less exfoliated, and bear no trace of the imbricate structure which is an essential feature of the species, while many are represented only by internal casts or external moulds.

In the course of this investigation I have examined material from various localities in the South-Western Province, and from the Irish localities cited by M'Coy. Two Irish specimens preserved in the Sedgwick Museum, Cambridge, which were presented to that Institution by Sir Richard Griffith and were named by M'Coy himself, afforded most useful information: for one is a testaceous specimen of a brachial valve of '*Spiriferina*' *laminosa*, from Hook Head, and the other an exfoliated specimen of a pedicle-valve from the 'Calp' of Bundoran,[2] resembling those so frequently found in the South-Western Province.

The discovery of specimens showing a cast of the interior and a mould of the exterior of the same shell, and a comparison between wax impressions of such casts and the internal structures as revealed by sections across the apex of the pedicle-valve, have established beyond doubt that the internal casts found in certain bands of dolomite in the middle part of the Avonian also belong to the same species.

The species under consideration differs from *Spirifer* in the presence of a well-developed median septum in the pedicle-valve; from *Spiriferina* in the absence of the coarsely-punctate shell-structure which characterizes that genus; and from *Syringothyris* in the absence of a transverse plate and syrinx, in the possession of a median septum, and in the imbricate surface-ornamentation. In the presence of a median septum accompanied by an impunctate shell it resembles the Silurian genus *Delthyris* (Dalman), but differs from any other species referred to that genus in its much greater size and its smaller and more numerous costæ, and also in the marked development of an apical callosity. There is, in the circumstances, no alternative but to regard it as belonging to a hitherto undescribed genus. It agrees in all its essentials with '*Spirifer*' *subconicus* (Martin), and I propose to assign those two species to a new genus, *Tylothyris*.

TYLOTHYRIS, gen. nov.

Description.—Shell spiriferoid, about twice as wide as long, greatest width along the hinge-line. Cardinal area moderately high, slightly concave or flat. Apical angle about 115°–120°.

[1] Dr. R. F. Scharff was good enough to institute a special search for this specimen in the collection in the National Museum, Dublin, and it may be definitely stated that it is no longer in that Institution.

[2] The register-numbers of these specimens are 635 & 636 respectively.

Delthyrium nearly twice as high as wide, delthyrial angle about 35°. Delthyrial covering unknown, although its former existence is indicated by grooves on each side of the delthyrium.

Pedicle-valve sub-pyramidal, lateral slopes convex or nearly flat; mesial sinus wide, subangular, and sharply differentiated by the subangular costæ on each side of it.

Brachial valve gently convex, mesial fold distinct, and raised above the general level of the valve, especially towards the anterior margin.

The lateral slopes in both valves are each ornamented by subangular costæ, decreasing gradually in size towards the cardinal extremities. Surface of both valves crossed by well-defined, regularly-disposed imbricating lines of growth, which are on the average about half a millimetre apart. Shell-structure fibrous and impunctate.

Internal structures:—Pedicle-valve.—Delthyrial supporting-plates divergent towards the floor of the valve. Median septum well developed, reaching nearly to the level of the area at the apex, becoming gradually lower and disappearing about halfway between the beak and the anterior margin of the valve. The earlier-formed portion of the median septum is embedded in the apical callosity, which near the beak completely fills the cavity between the delthyrial supporting-plates, and extends forward along the floor of the valve, connecting those plates with the median septum, on each side of which, at the termination of the callosity about half-way along the median septum, there is a pit-like depression which gives a very characteristic appearance to the internal cast. (See text-figs. 1 *m* & 1 *n*, p. 166, and Pl. XIII, fig. 12.)

Brachial valve.—There is a low median crest or septum. Brachial skeleton and jugum imperfectly known.

Range.—Carboniferous Limestone, *Cleistopora* Zone to Upper *Dibunophyllum* Zone.

Genotype.—*Tylothyris laminosa* (M'Coy).

Systematic position.—The systematic position of *Tylothyris* cannot be stated with absolute certainty. The median septum is only a special development of a feature represented in most of the Spirifers, and cannot be regarded as of more than generic value.

The absence of punctæ in the shell-substance connects it with *Spirifer* rather than with *Spiriferina*.

The spiral coils, as seen from the rubbing-down of the brachial valves of several specimens, are arranged with their apices directed laterally outwards, that is, in the way normal to *Spirifer* and allied genera. There is no evidence to suggest that the coils were spinose, as in the Jurassic species of *Spiriferina*. Owing to the mode of preservation of the shells, indubitable evidence of the precise nature of the jugum has not been obtained. Small fragments of shelly rod were observed in some specimens in the position in which the jugum would be expected to occur. They were, however, obviously disturbed, and it was not possible to determine whether they

represented a continuous jugum such as is present in *Spiriferina*, or mere jugal processes like those of, for instance, *Spirifer striata*.[1]

On the classification given in the second English edition of Zittel's 'Palæontology,' *Tylothyris* would appear to belong to the sub-family Trigonotretinæ, Schuchert; it certainly does not belong to the family Suessiidæ, which includes *Spiriferina*.

TYLOTHYRIS LAMINOSA (M'Coy) emend. (Text-figs. 1*m*, 1*n*, 4*a*, & 4*b*, pp. 166, 199; Pl. XIII, figs. 1, 2, 12, 13, & 16.)

1844. *Cyrtia laminosa* M'Coy [20] p. 137 & pl. xxi, fig. 4.
1844. *Spirifera decemcostata* M'Coy, *op. cit.* p. 131 & pl. xxii, fig. 9.
1844. *Spirifera mesogonia* M'Coy, *op. cit.* p. 137 & pl. xxii, fig. 13.
1855. *Spirifera laminosa* M'Coy [21] p. 426.
1887. *Spiriferina laminosa* De Koninck, Ann. Mus. Roy. Nat. Hist. Belg. vol. xiv, pt. 6, pp. 103–105.
1905. *Syringothyris* aff. *laminosa* Vaughan, 'Bristol Paper' [33] p. 300.
1911. *Syringothyris laminosa* (auctt.) Vaughan, 'Burrington Paper' [28] p. 383 & pl. xxxi, fig. 8.

Description.—Shell spiriferoid, of medium size, about twice as wide as long; greatest width along the hinge-line.

Pedicle-valve sub-pyramidal, cardinal area rather more than three times as wide as high, concave, nearly flat in the neighbourhood of the hinge-line, but with increasing curvature towards the beak, which is very slightly incurved; apical angle about 120°. The beak of the pedicle-valve lies considerably above a line perpendicular to the plane of the brachial valve (see text-figs. 4*a* & 4*b*, p. 199). Delthyrium nearly twice as wide as high, delthyrial angle about 35°. Delthyrial covering unknown. Lateral slopes evenly convex; mesial sinus wide, subangular, and terminating in a rounded wave at the anterior margin of the valve. A line along the floor of the sinus from the beak to the anterior margin is evenly curved.

Brachial valve convex, the greatest convexity being in the neighbourhood of the beak. Mesial fold narrow at its commencement, but increasing rather rapidly in width towards the anterior margin, where it is considerably raised above the general level of the valve.

Each lateral slope in both valves is ornamented by ten or twelve simple costæ decreasing gradually in size towards the cardinal extremities; the last four or five costæ are short and inconspicuous. They are subangular, and are separated by deep furrows, each about as wide as the costæ on each side of it.

Surface of both valves, except the cardinal area of the pedicle-valve, crossed by well-defined, regular, imbricating lamellæ of growth, which are, on the average, about half a millimetre apart. Shell-structure foliaceous, fibrous, and impunctate.

Internal structures:—Pedicle-valve.—The delthyrial

[1] The jugum is the transverse shelly band and its accessory processes which unite the primary lamellæ of the spiralia. If the band is incomplete, its parts are known as 'jugal processes.'

supporting-plates extend completely across the cavity of the valve, and are divergent, enclosing between them an angle of about 35°: median septum well developed, reaching nearly to the level of the area at the apex, becoming gradually lower, and disappearing about half-way between the beak and the anterior margin. The septum is, at its base, about as thick as the shell itself; but it tapers rather suddenly, and becomes very thin. Its apical portion is completely embedded in the apical callosity, the structure of which is typical of the genus, and has already been described.

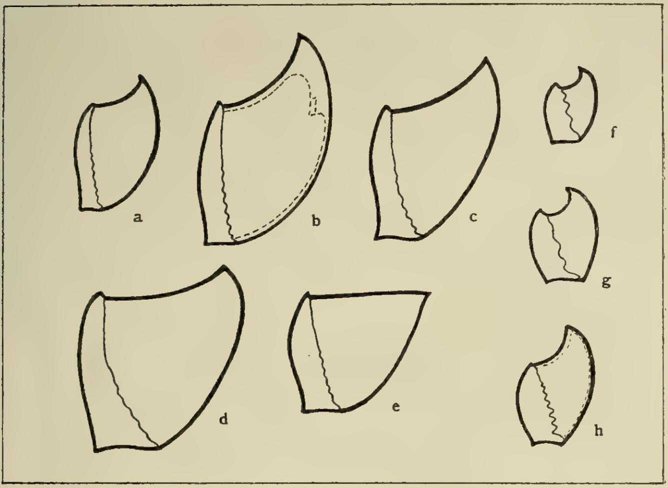
Remarks:—Shell-structure.—The majority of the Irish specimens are silicified, and afford no evidence as to the microscopic structure of the shell; but in suitably-preserved examples I have found no conclusive evidence of punctæ, neither when the shell is examined with a hand-lens, nor when fragments are examined under the microscope. The absence of punctæ cannot be due to recrystallization, because the fibrous structure is clearly preserved. The species under consideration cannot be readily distinguished from *Syringothyris* on the minute shell-structure, but it cannot possibly be confused with *Spiriferina*. A lamellose Spiriferid from the Bernician of Redesdale (Northumberland), dealt with in a later section of this paper, has a coarsely-punctate shell, and William King, supposing it to be identical with the species under consideration, assumed the existence of punctæ in that species, which he, in consequence, referred to *Spiriferina*.

Internal casts.—Owing to the development of the apical callosity, an internal cast of the pedicle-valve of *T. laminosa* possesses distinctive characters. As will be seen from an examination of text-fig. 4 *b* (p. 199) its profile differs considerably from that of the external surface. The precise nature of the cast will be best understood by reference to Pl. XIII, fig. 12, where the central conical portion (*a*) represents the cavity between the delthyrial supporting-plates, and the lateral cones (*b*) the cavities on each side of it; towards the centre of the figure are the casts (*c*) of the pit-like depressions at the anterior end of the apical callosity, and between them is the narrow fissure (*d*) left by the unembedded portion of the median septum. The significance of these structures will be at once apparent if they are compared with Pl. XIII, fig. 15, which illustrates the actual plate-system and apical callosity in a specimen of *T. subconica* (Martin). They should be contrasted with Pl. XIII, fig. 14, which depicts an internal cast of a typical *Spiriferina*: namely, *Sp. walcotti*.

Internal casts such as those described were found by Principal T. F. Sibly in dolomites of the Lower *Caninia* Zone in the Mitcheldean district, and they also occur in abundance in deep-red dolomites at Tynant Quarry, Taff's Well, near Cardiff.

Holotype (of the emended species).—A specimen (brachial valve) from Z, Hook Head (Wexford), in the Museum of Practical Geology (Reg. No. 28425).

Fig. 4.—*The profiles of* Tylothyris, Spiriferina, *and* Punctospirifer. *(The broken lines in* b *and* h *represent the contour of the interior of the shell.)*



a = *Tylothyris laminosa* mut. β.
b = *Tylothyris laminosa* mut. γ.
c = *Tylothyris*, between *laminosa* and *subconica* (C–S).
d = *Tylothyris subconica castletonensis* (D).
e = *Tylothyris subconica subconica* (D).
f = *Spiriferina insculpta*.
g = *Spiriferina octoplicata*.
h = *Punctospirifer scabricosta*.

Mutations of *Tylothyris laminosa*.

The species in its typical condition is characteristic of beds of Z_2–C_1 age, but it is also represented in K and in Z_1.

(*a*) Tylothyris laminosa mut. β includes small specimens from K and Z_1, in which there are indications of all the essential characters of the species.

Description.—*T. laminosa* mut. β differs from the typical form of the species in the following respects:—The shell is smaller and the area less elevated, the costæ are more sharply defined, and the development of the apical callosity is less pronounced. The dimensions of an average specimen are as follows:—width along hinge-line, 24 mm.; height of area, 6 mm.; length of brachial valve, 12 mm.

Horizons and localities.—K_1 in the Upper Neath Valley,[1] K_2 at Mitcheldean and Burrington,[2] and rarely in Z_1 in the Mendip area generally.

[1] Collected by the late Mr. C. H. Cunnington.
[2] Vaughan [28] p. 384.

(*b*) TYLOTHYRIS LAMINOSA mut. γ. Mutation γ is the form which most closely approximates to the description of the species already given.

Horizons and localities.—Mutation γ is particularly characteristic of the upper beds of the Lower Avonian in the South-Western Province. It does not everywhere attain its maximum at the same horizon. In the Mendip area it is particularly characteristic of Z_2, of Horizon γ in the east of Glamorgan, and of the *laminosa* dolomites (C) in the Avon Section.

The dimensions of an average specimen are as follows:—width along the hinge-line, 30 mm.; length of brachial valve, 15 mm.; height of area, 8 mm. Generally speaking, there is a slight increase in size and a greater development of the apical callosity in the shells from Horizon γ and C_1, but the differences are small; and, owing to the varying mode of preservation, the form characteristic of any particular horizon cannot be definitely described in exact terms.

Further notes on *T. laminosa*.—Locally, the species reaches larger dimensions, and in such places usually seems to be particularly abundant. This is noticeable, for example, at Barry (Glamorgan), where in size, and in the intensification of certain characters the shells from γ–C recall the special forms of *Syringothyris* found in the knoll-limestones, and in the Midland 'Brachiopod-Beds.' An unusually large specimen from the Cadoxton inlier, near Barry, had the following dimensions:—width along hinge-line, 40 mm.; height of area, 12 mm.; length of brachial valve, 20 mm.[1] *T. laminosa* is not widely distributed above C_1. Vaughan mentions it as being rare in C_2 in the Gower Peninsula,[2] and as occurring in abundance in a band at one level in S_1 in the Avon Section.[3]

In Ireland it has been found in Z (? C_1) at Hook Head and at Malahide; in Z_2 (but not in C_1) in Clare[4] and at Bundoran. Large and small forms occur, as in England and Wales; but there is not at present sufficient evidence to admit of a discussion of the zonal significance of the species in all the localities mentioned. The typical form occurs also in Belgium, as, for example, at Allain.[5]

The cardinal extremities are frequently broken off, as in the specimens from Burrington figured by Vaughan[6]: this gives to the shell a deceptive rounded appearance, but the precise nature of the cardinal extremities is usually indicated by the imbricating growth-lines, when they are preserved. The loss of the cardinal extremities

[1] In this connexion it is interesting to recall Mr. E. E. L. Dixon's suggestion that knoll-reefs may be expected to occur in the Barry area, similar to those discovered near the junction between the Lower Avonian and the Upper Avonian in Pembrokeshire. In the discussion of a paper by F. Dixey & T. F. Sibly [6] p. 162.

[2] Vaughan [7] p. 546.

[3] Vaughan [33] p. 195.

[4] Douglas [8] p. 549.

[5] Vaughan [35] p. 39; see also pl. vi, figs. 1–3.

[6] Vaughan [28] pl. xxxi, fig. 8.

also results in the disappearance of the last three or four costæ, giving the impression that there are only six or seven bold plications on each side of the field.

In exfoliated specimens the costæ appear to be stouter and less angular than when the shell is preserved. Judged by the figures, the specimens referred to by M'Coy as *Spirifera decemcostata* and *Sp. mesogonia* were in all probability exfoliated examples of *Tylothyris laminosa*; but, as neither of these forms is adequately defined by M'Coy's description and figures, and as the original specimens are no longer in existence,[1] the names are best regarded purely as synonyms of that species.

M'Coy said of the species 'mesial hollow produced when old into a long, tongue-shaped, flattened lobe,'[2] and Davidson figured a form possessing that character, which is, however. not of common occurrence.

Davidson's figures are greatly restored and idealized, and appear to have been based upon three imperfect specimens now in the Sedgwick Museum. These I have been able to examine through the kindness of Dr. F. R. Cowper Reed, and they bear very little resemblance to the figures. Dr. Reed wrote concerning them:—

> 'Indeed, unless we knew that these were the actual specimens which he (Davidson) used, and to which he referred, one might hesitate to accept them as the types.' *(In litteris.)*

Apart from the prolongation of the floor of the sinus, the specimens are nearer to *T. subconica* than to *T. laminosa* in the height and curvature of the area. The locality is given as Derbyshire, but the horizon is not known.

Comparison with *T. subconica*.—*Tylothyris laminosa* and its mutations are readily distinguished from *T. subconica* by the greater concavity of the area (compare figs. 4 *a*, 4 *b*, & 4 *d*, p. 199). In *T. subconica* the sinus and the costæ are more angular, the line along the base of the sinus less curved, and the fold less elevated than in *T. laminosa*.

Shells incorrectly referred to *Tylothyris laminosa* (M'Coy).—A number of shells which do not really belong to that species have been referred to *T. laminosa*, on account of their laminose ornament. Two of these are of sufficient interest to be dealt with separately:—

(1) '*Spiriferina laminosa*' from beds of *Dibunophyllum* age at Redesdale (Northumberland) and other localities, so named by King;

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[1] These specimens, together with the holotype of M'Coy's *Sp. laminosa* and others, were formerly in the 'Griffith Collection,' but their whereabouts are now unknown. Dr. R. F. Scharff very kindly caused a fresh search to be made for them in the collection of the National Museum, Dublin, but without success; and they have not hitherto been recognized in any public collection, although Davidson speaks of having examined the type of *Sp. decemcostata* [4] p. 43. In all probability the original figures were, as was often the case, idealized, so that actual specimens, if met with, would pass unrecognized.

[2] M'Coy [21] p. 426.

and mentioned by Vaughan in his Belgian paper.[1] (See text-fig. 5 j, p. 211; Pl. XIII, fig. 6.)

(2) Shells occurring in the *Productus corrugato-hemisphericus* zone (S) of the Ravenstonedale district, doubtfully referred to '*Spiriferina laminosa*' by Prof. E. J. Garwood.[2] (See text-fig. 5 *g*, p. 211.)

They are undoubtedly time-variants of one and the same species, but cannot be included in M'Coy's *laminosa*, from which they differ in shell-structure and in the non-development of the apical callosity. They differ from a typical *Spiriferina* in having numerous small, somewhat rounded costæ, and in the relatively large rounded fold and sinus. Those forms will be referred to a new genus, *Punctospirifer*, and will be considered after a general discussion of the Carboniferous 'Spiriferinas' and their relation to the type-species of that genus.

Certain other Spiriferoid shells in the Carboniferous Limestone have a strong imbricate ornament, and might, especially in fragmentary specimens, be confused with either *T. laminosa* or *Punctospirifer*. They have, however, an impunctate shell-structure, and no ventral median septum, and must therefore remain at present in the protean 'genus' *Spirifer*. They may be readily distinguished from the other lamellose genera discussed in this paper by their transverse shape, mucronate cardinal extremities, and particularly by their low incurved *Spirifer*-like area and numerous small costæ. They include forms such as occur in the *Dibunophyllum* Zone in the Midlands, and externally have much in common with the North American Devonian species. *S. pennatus* Atwater (= *S. mucronatus* Conrad).

Tylothyris subconica (Martin).[3]

The original description and figures do not adequately define this species, and the name has in consequence been made to include more than one form. It is therefore, as in the case of *T. laminosa*, necessary to re-define the species. Unfortunately the holotype has been lost, and I am unaware of the existence of any specimen from the original locality which could serve as a topotype.

Forms which can be referred to this species are found in Derbyshire and Staffordshire, the Craven district, and in Ireland, in each case in the upper beds of the *Dibunophyllum* Zone.

The shells may be divided into two groups, in one of which the area is slightly incurved at the beak, while in the other the area is practically a plane triangle. These two groups are not strictly time-variants, neither do they entirely owe their characters to the type of deposit in which they occur, although both factors play some part in their differentiation. They are best regarded as sub-species of *T. subconica*.

[1] Vaughan [35] p. 44.

[2] Garwood [13] p. 572 & pl. li, figs. 7 *a*–7 *e*, text-fig. 7.

[3] Not *Spirifera subconica* Phillips, which is a synonym of *Cyrtina heteroclita*.

Tylothyris subconica subconica (Martin) emend. (Text-fig. 4 *e*, p. 199; Pl. XIII, figs. 5 *a*–5 *c*.)

1809. *Conchyliolithus anomites subconicus* Martin, 'Petrifacta Derbiensia' pl. xlviii, figs. 6–8.
1858. *Spirifera subconica* Davidson [4] p. 48 & pl. ix, figs. 3, 3 *a*, 3 *b*.
1906. *Syringothyris subconica* Vaughan, 'Rush Paper' [31] p. 311 & pl. xxx, fig. 7.

This subspecies includes the form upon which the species was originally founded, since in the original account Martin described his specimen as having an area 'which is straight, and not recurved as in *cuspidatus*.' His figures also indicate a flat area.

Description.—Shell spiriferoid, of medium size, twice as wide as long, greatest width along the hinge-line, cardinal extremities slightly produced.

Pedicle-valve acutely pyramidal, cardinal area practically a plane triangle, a little more than twice as wide as high; plane of the area at right angles to that of the brachial valve, its lateral edges well defined and angular. Apical angle about 115°.

Delthyrium twice as high as wide, delthyrial covering unknown.

Lateral slopes slightly convex or nearly flat. Sinus angular, sharply defined by angular ridges diverging at an angle of about 30°. The line along the floor of the sinus from the beak to the anterior margin is very slightly curved or practically flat.

Brachial valve slightly convex, nearly semicircular in outline. Mesial fold distinct, low, and rounded; its convexity decreases towards the anterior margin, while that of the lateral slopes increases in the same direction.

Each lateral slope in both valves is ornamented by ten or eleven simple angular costæ of which the first six or seven on either side are large and well developed, the remainder being short and inconspicuous and not apparent in exfoliated specimens. In some specimens the costæ are slightly sinuous; they are separated by furrows approximately equal in depth and width to the costæ on each side of them. Surface of both valves, except the cardinal area, marked by regular imbricating lamellæ.

Internal structures:—Pedicle-valve.—The delthyrial supporting-plates extend across the cavity of the valve, and are divergent. Median septum well developed, reaching nearly to the level of the area near the beak, becoming gradually lower, and disappearing about half-way between the beak and the anterior margin. The apical portion of the septum is embedded in the apical callosity, which is well developed.

In the brachial valve there is a low median septum extending for about two-thirds of the distance from the beak to the anterior margin.

Shell-structure fibrous and impunctate. The dimensions of an average specimen are as follows:—width along hinge-line, 36 mm.; length of brachial valve, 18 mm.; height of cardinal area, 15 mm.

Holotype (of *S. subconica subconica*).—A specimen from Attermire, in my collection, now deposited in the National Museum

of Wales. Other examples, from Settle, are on a tablet numbered 501 in the Sedgwick Museum, Cambridge.

Horizon and localities.—Upper *Dibunophyllum* Zone (D_2–D_3). Principal Sibly reports it as being characteristic but rare in D_3 in Derbyshire and North Staffordshire,[1] while in Ireland it is characteristic of the *Cyathaxonia* Beds (D_3) at Rush[2]; Martin's figured specimen was recorded as from Middleton (Derbyshire). A number of specimens from the neighbourhood of Settle are in the Sedgwick Museum.

Remarks.—In the original description of '*A. subconicus*,' Martin compared this species with his '*Anomites cuspidatus*,' from which it differed in having fewer and more angular ribs, and a flat area. He said that, in the shape of its area, it was intermediate between that species and another undescribed form with a more incurved area; this form was, in all probability, *Tylothyris laminosa*. Davidson expressed a doubt as to whether Martin's species was only an exceptional variety of *S. cuspidata*, and reproduced Martin's figures.[3] In his appendix to the 'Carboniferous Brachiopoda,' Davidson figured a testaceous specimen of *T. subconica* in which the lamellose ornament was perfectly preserved, and admitted its specific distinction from *S. cuspidata*, but compared it to *S. laminosa*.

De Koninck stated that the lamellar ornament occurred in young shells only,[4] and was absent or scarcely visible on adult specimens; but that author, owing no doubt to the state of preservation of his material, apparently regarded *Cyrtina septosa* (Phillips) as the adult form of *T. subconica*, for the form which he figures as the latter species is certainly *C. septosa*.

The lamellar ornamentation is not often preserved; in exfoliated specimens the costæ are smooth, and appear more rounded than in perfect shells.

Tylothyris subconica castletonensis, subsp. nov. (Text-fig. 4 *d*, p. 199; Pl. XIII, figs. 3, 4 *a* & 4 *b*.)

This form differs from *T. subconica subconica* in the following respects:—The shell is rather less transverse, and the cardinal extremities are blunter, being practically right angles. The costæ are stronger, less angular, and towards the cardinal extremities are less clearly defined than in the other subspecies. The sinus is shallower and less angular, and the line along its floor more strongly curved than in *T. subconica*. The area is more or less concave, and terminates in a small, incurved, pointed beak (see fig. 4 *d*, p. 199).

[1] Sibly [31] p. 51.

[2] Vaughan [34] pl. xxx, fig. 7.

[3] Davidson [4] p. 48 & pl. ix, figs. 3, 3 *a*, 3 *b*. These figures were apparently copied on the stone directly from Martin's drawings, and are therefore reversed.

[4] De Koninck [19] p. 255 & pl. xii *bis*, figs. 5 *a*–5 *c*. (Really figs. 4 *a*–4 *c*, although in the text, as well as in the explanation of the plate, he cites them as 5 *a*–5 *c*; fig. 5 is a species of *Chonetes*.)

Horizon and localities.—Upper *Dibunophyllum* Zone (D_2) Wetton (Staffordshire); Castleton, etc. This form is more particularly characteristic of the 'Brachiopod-Bed' type of deposit, and its relation to *Tylothyris subconica subconica* recalls that which exists between the forms of *Syringothyris* occurring in normal deposits, and the special types found in the knoll-phase limestones.

Holotype (of *T. subconica castletonensis*).—A specimen from Settle on Tablet 501, in the Sedgwick Museum, Cambridge.

Comparison with *Syringothyris cuspidata*.—*T. subconica subconica*, *T. subconica castletonensis*, and *S. cuspidata* sometimes occur in the same beds, and have frequently been confused. The difference between the first two and the last is, of course, at once evident if the beak of the pedicle-valve is broken, or is rubbed down; but there are also external differences. Compared to either of the species of *Tylothyris* with which it can occur, *S. cuspidata* is a larger shell, has a higher area, more numerous and less angular costæ, and a less sharply-defined sinus in the pedicle-valve. Moreover, it never exhibits the lamellose ornament seen in suitably-preserved specimens of *Tylothyris*. The shell recorded by Phillips as a 'remarkable variety of *Spirifera cuspidata*' was in all probability *T. subconica*.[1]

Comparison with *T. laminosa*.—The flat area of *T. subconica subconica* at once distinguishes it from *T. laminosa*. *T. subconica castletonensis* differs from that subspecies in its higher area, the beak of which is not much raised above a line perpendicular to the plane of the brachial valve. The fold is more elevated, and the line along the floor of the sinus more strongly curved in *T. laminosa* than in the later species.

Certain shells occurring in the *Dibunophyllum* Zone which are more or less intermediate between *T. subconica castletonensis* and *T. laminosa*, but more closely resemble the latter species, are included under that name, as no useful purpose would be served by attempting to differentiate them. They include forms like that figured by Davidson,[2] and the specimen from Bundoran mentioned by him on p. 156 (see fig. 4 *c*, p. 199). This latter form from the 'Calp,' which includes representatives of S_2 and D, is in all probability intermediate in age between *T. laminosa* and *T. subconica*. Here also belongs a specimen referred to by Martin in his description of *Anomites cuspidatus*. He says:

> 'In the other anomite which I have not as yet named or described the hinge is still less than in *A. subconicus*, and the beak of the large valve instead of being straight is somewhat incurved.'

J. Parkinson, in his 'Organic Remains,' figured what he believed to be the form to which Martin referred. His figure shows clearly the curved area and the laminose surface-ornament.[3]

[1] Phillips [27] p. 216.
[2] Davidson [4] p. 36 & pl. vii, figs. 21–22.
[3] Parkinson [26] p. 235 & pl. xvi, fig. 16.

Tylothyris subconica is, therefore, connected by intermediate forms with the Lower Avonian species, *T. laminosa*, from which it undoubtedly descended. So far as I have been able to ascertain, there are no representatives of *Tylothyris* in Permian or newer beds, and, as in the case of *Syringothyris*, its pre-Carboniferous history in Britain is at present unknown.

V. The Relation between *Spiriferina* and *Syringothyris*.

The late Dr. Arthur Vaughan, in his 'Bristol Paper,' compared certain Spiriferoid shells from the 'Upper Tournaisian' of the Avon section with M'Coy's species '*Spirifera laminosa*,' and later [35] p. 43, definitely expressed the opinion that they did indeed belong to that species, an opinion which has now been fully confirmed. Dr. Vaughan, however, referred the species to the genus *Syringothyris*, remarking, [33] p. 301, that

'within the delthyrium there is a distinct rostral callus and a trace of a syrinx. I have not as yet obtained unequivocal proof of the existence of a syrinx, but the presence of the rostral callus is indisputable.'

In a later paper, [28] p. 383, he stated that

'wholly or partly buried within this callus is an infilled syrinx that can be seen half projecting along the middle line of the callus, and in weathered specimens is represented at the apex by a short narrow rod. A cross-section near the beak shows the infilled syrinx and the dental-plates; at a little distance below the beak the strong mesial septum begins to appear.'

No specimen that I have examined affords any justification for assuming the existence of a syrinx embedded in the apical callosity, and in the absence of a figure it is impossible now to determine the precise nature of the structure to which Vaughan referred. His allusion to a short narrow rod seen in the apex of weathered specimens suggests that it may have been the edge of the median septum projecting through the upper surface of the apical callosity; but, in any case, it cannot have been comparable with the syrinx of *Syringothyris*, for the following reasons:—

(1) The essential characters of *Syringothyris* do not appear in sections immediately under the beak. (See fig. 1 *a*, p. 166.)

(2) There is no elevated median septum in the ventral valve of *Syringothyris*.

(3) The two structures, a median septum and a syrinx-bearing transverse plate, could not coexist in the same shell, since they would mutually interfere one with the other.

(4) Sections (see figs. 1 *m* & 1 *n*, p. 166) across the beak of *Tylothyris laminosa* clearly show that it is not a *Syringothyris*.

(5) No known specimen of *Syringothyris* has the imbricate ornament of *T. laminosa*.

Vaughan recorded the close connexion between the species *T. laminosa* and *T. subconica* in the following terms:—

'*S. subconica* is so similar to *S. laminosa* that its specific separation has been viewed with scepticism. There seems, indeed, to be no reasonable doubt

that *S. subconica* is the direct descendant of *S. laminosa*, and differs only in the accentuation of the traits already adumbrated in the earlier form.' [1]

But he further states that

'A cross-section of the beak of *S. subconica* reveals the characters of *Syringothyris* as typically developed as in *S. cuspidata* (Mart.) itself.'

This, however, is certainly not the case. *S. cuspidata* and *S. subconica* frequently occur together, as, for example, at Settle; and small specimens of the former bear some slight resemblance, externally, to exfoliated specimens of the latter, although the difference between the two is at once manifest when the beaks are rubbed away, and the cross-section examined. It was apparently upon a small, wrongly-identified specimen of the former species that Vaughan based the statement just quoted.

Unfortunately, from the supposed existence of the syrinx in *T. laminosa* and the assignment of *T. subconica* to *Syringothyris*, Vaughan drew certain conclusions regarding the phylogeny and relationship of the two genera *Spiriferina* and *Syringothyris*:--

'Hence, *S. laminosa* develops, phylogenetically, into a typical *Syringothyris*.... The results obtained indicate the close relationship in Carboniferous times of the two genera *Spiriferina* and *Syringothyris*.... The most probable guess is, that *Spiriferina* and *Syringothyris* were both derived at much the same time from a common ancestral group, and that they developed along different lines, but that in the earliest period of their history they possessed the same essential structure.' [*Loc. cit.*]

Sufficient evidence has already been adduced to show that this assumption is not supported by observed facts, for *T. laminosa* is not a *Spiriferina*, and that genus and *Syringothyris* have practically nothing in common. What is already known concerning the evolution of *Syringothyris* shows that at no period of its history did its ancestors show any sign of the development of the essential features of *Spiriferina*: namely, a strongly-punctate shell-structure and an elevated median septum in the pedicle-valve. Finally, there are early Palæozoic Spiriferoids with an imbricate ornamentation of the shell and a pronounced median septum, among which to look for the ancestors of *Spiriferina*.

It is evident that further study of the subject was causing Vaughan to modify his views, and but for his untimely death would in all probability have cleared up the uncertainty which had resulted from his interpretation of *T. laminosa*. In his last paper, he speaks of two forms included under that name. One of these, characteristic of the Lower *Caninia* Zone, he still regarded as a *Syringothyris*, while the other, characteristic of the Upper *Zaphrentis* Zone, with a primitive and buried syrinx and an impunctate shell-structure, he considered to be a *Spirifer*, or a rudimentary *Syringothyris*. He definitely stated that neither is a *Spiriferina*, and added: 'In any case, it is not possible to separate usefully the two forms in field-work.' [2]

[1] Vaughan [28] p. 384.

[2] Vaughan [35] p. 44.

Of these two forms, the second is undoubtedly the *Zaphrentis*-Zone mutation of the species here described as *T. laminosa*, but the identity of the first is not so clear. To illustrate it, Vaughan quoted the figure of a specimen from Horizon γ at Burrington Combe,[1] and describes it as having fewer ribs than the second form. The cardinal extremities of the figured specimen are broken, and this, as has already been mentioned, conveys the impression that the shell possesses fewer ribs than it actually does. The figure so closely resembles an exfoliated Z_2 specimen as to suggest that Vaughan's two forms are time-variants of the same species.

VI. Spiriferina D'Orbigny.

Shells referred to *Spiriferina* occur in Carboniferous, Permian, and Liassic deposits in the British area; and elsewhere in the Trias, where that formation includes marine deposits. It has, in fact, been customary to regard all Spiriferoid brachiopoda in which a ventral median septum coexisted, or was supposed to coexist with a punctate shell-structure, as *Spiriferina*, merely because there was no other genus to which they could conveniently be referred, and not from any failure to recognize the polyphyletic nature of the species involved.

The genotype of *Spiriferina* is a Liassic shell (*Sp. rostrata* Schlotheim), and before we attempt to discuss the Palæozoic forms, some account of the genus in its original sense is necessary.

The genus *Spiriferina* was established by D'Orbigny, in 1847,[2] for certain Liassic brachiopoda previously included in *Spirifer*, but which differed from typical members of that genus in the possession of a vertical shelly septum in the ventral valve, and in the existence of abundant relatively-large canals or punctæ in the shell-structure.

It is somewhat unfortunate that D'Orbigny took as his genotype *Sp. rostrata* Schlotheim, because in external appearance that species is not typical of the genus. It has a uniformly rounded, or even globose shell, the surface of which may be quite smooth, or at the most only slightly undulated; while in the other species there is usually a radial ornament consisting of well-defined angular costæ.

External characters:—Shape and dimensions.—The shell is ovate, and the hinge-line less than the greatest diameter of the shell. The cardinal extremities are rounded, and the lateral slopes of each valve tumid. The size is variable, but the dimensions of an average specimen are—width along hinge-line, 28 mm.; length of brachial valve, 21 mm.

Usually, as in *Sp. walcotti*, the ornament consists of a few prominent angular costæ separated by V-shaped furrows, on each side of a median fold in the brachial valve and a corresponding sinus in the pedicle-valve. The fold and sinus are more or less angular and resemble the costæ and furrows, from which they differ only in size.

[1] Vaughan [28] pl. xxxi, fig. 8.
[2] C. R. Acad. Sci. Paris, vol. xxv (1847) p. 268.

The plications of the shell impart to the anterior margin a characteristic serrate appearance.

The surface of the shell is marked by a few concentric imbricating lamellæ of growth, widely spaced in the umbonal region, but closely crowded anteriorly. In well-preserved specimens the outer layer is covered with fine, tubular, spinose projections, which when broken, as is usually the case, give to the shell a characteristic pustulose appearance.

The area.—The area of the pedicle-valve is variable in height, but the average apical angle is 140°. When the area is low it is strongly incurved, though as its height increases it becomes flatter; the plane of the area is always inclined to the plane of the brachial valve, so that the apex of the pedicle-valve is above that of the opposite valve. The area is defined by a pair of lines diverging from the apex, and outside of which the shell gradually curves over into the lateral slopes.

The delthyrial angle is about 40°. In his original description D'Orbigny stated that the 'delthyrial aperture' was without covering; but this was due to the imperfection of his specimens. The delthyrial covering consists of a pair of imperforate deltidial plates slightly inclined one to the other to form a roof-like structure. The delthyrial covering is rarely preserved; but its former existence is indicated by the grooved margins of the fissure.

Shell-structure.—The shell is fibrous and strongly punctate: that is, perforated by comparatively-large canals which appear to push the fibres aside. The canals communicate with the interior of the shell, so that the surface of well-preserved internal casts is granulated.

Internal structures:—Pedicle-valve.—The delthyrial supporting-plates are well developed, diverge towards the floor of the valve, and their anterior extremities are concave. The ventral median septum is well developed. It is attached to the floor of the valve for about a third of the distance between the apex and the anterior margin; near the apex it extends to the level of the area, and it terminates anteriorly in a curved blade-like process.

An apical callosity is developed to a variable but never very great extent, and although the extreme apical portion of the valve is solid, the callosity has but little influence on the internal cast.

The spiral coils in the brachial valve are large, and have their apices directed laterally; their anterior portion is spinose. The jugum is a complete simple transverse band, connecting the primary lamellæ of the spires near their junction with the crura.

The essential characters of *Spiriferina*, as portrayed by the Liassic species, may be summarized as follows:—Hinge-line not greater than the diameter of the shell; cardinal extremities rounded; area moderately low and curved; distinct incurved beak; few angular costæ; angular fold and sinus not sharply differentiated from the costæ; well-developed ventral median septum; coarsely-punctate shell-structure.

The possession of the two last-named characters is not alone sufficient to justify the reference of a shell to *Spiriferina*.

(*a*) Pre-Liassic Species referred to *Spiriferina*.

A general discussion of the shells from infra-Liassic formations hitherto referred to *Spiriferina* is beset with many difficulties. In this country the sequence is interrupted by the non-fossiliferous Triassic rocks, the conditions necessary for the formation of which must have profoundly affected the life of the times: and, assuming that the Liassic shells are homogenetic with some of the Carboniferous species, the enforced migration in post-Carboniferous times may be expected to have induced considerable changes in the animals, before their descendants returned to this area with the expanding Liassic sea.

The paucity of our knowledge of the brachidia and associated structures of the earlier species is also unfavourable to their satisfactory classification. This might, indeed, be urged as a reason against attempting any generic differentiation; but, since the opportunities of obtaining evidence of this nature are so few, and there are certain persistent differences in external appearance, involving both contour and ornamentation (the only characters of any real value to the field-worker). a scheme of classification based mainly, but not exclusively, upon these features seems justifiable.

The laminose-punctate-septate Spiriferids may be divided on external characters into at least two well-defined series:—

(1) Shells with an almost flat, triangular. moderately-high area, with angular margins, by which it is sharply differentiated from the lateral slopes: beak inconspicuous and pointed. fold and sinus well developed, rounded. and considerably larger than the costæ, of which there are about six or seven on each lateral slope. The greatest width of the shell is at the hinge-line. The anterior margin has a large rounded median fold, and is wrinkled laterally. (See figs. 5 *f*–5 *j*, p. 211.)

(2) Shells with curved area, the margins of which are more or less rounded, and curve over into the lateral slopes; small incurved beak in the pedicle-valve. There are a few large angular costæ, and an angular fold and sinus structurally like the costæ and furrows, than which they are only a little wider. The anterior margin of the valves is strongly serrated, with a few sharp folds. decreasing in amplitude from and including the median fold. (See figs. 5 *a*–5 *e*.)

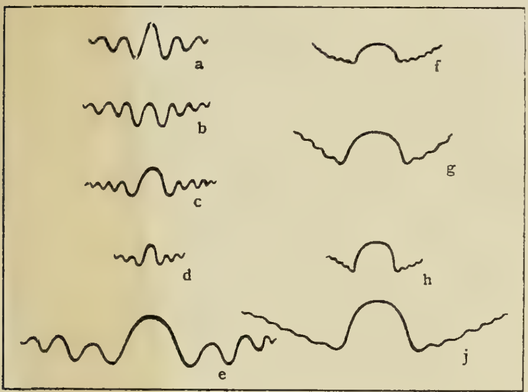
These distinctions apply to shells in both Palæozoic and Mesozoic formations. In the Carboniferous Limestone the first type is represented by the Ravenstonedale and Redesdale forms already mentioned (and hitherto referred to *Spiriferina laminosa*), and the second by *Spiriferina octoplicata*. In the Permian, both types occur among the shells referred to the imperfectly understood species, *Sp. cristata* (fig. 5 *d*) and *Sp. multiplicata* (fig. 5 *h*), and they both also occur in the marine Triassic deposits of South-Eastern and Central Europe. In the Lias the first type is represented by *Spiriferina oxygona* (fig. 5 *j*), and the second by *Sp. walcotti* (fig. 5 *e*).

In this paper it is proposed to assign the Carboniferous species belonging to the first of those two types to a new genus, *Puncto-spirifer*; those belonging to the second type are best regarded as

Spiriferina, until more evidence as to their internal structures is available.

The Carboniferous 'Spiriferinas' of North America also comprise two similar groups. The first type is there represented by *Sp. kentuckyensis*, in which the plications are small, numerous, and crossed by closely-packed concentric lamellæ; while the second is represented by forms like *Sp. spinosa*, which strongly resembles the British *Sp. octoplicata*.[1] According to J. Hall & J. M. Clarke, the jugum of *Sp. kentuckyensis* differs from that of the Liassic *Sp. rostrata*

Fig. 5.—*Form of the anterior margin of the valves of* Spiriferina *and associated genera.*



a = *Spiriferina insculpta*, Carboniferous Limestone (D).
b = *Spiriferina octoplicata*, Carboniferous Limestone (D).
c = *Spiriferina perplicata*, Carboniferous Limestone (D).
d = *Spiriferina cristata*, Permian.
e = *Spiriferina walcotti*, Lower Lias.
f = *Punctospirifer scabricosta* mut. *redesdalensis*, Carboniferous Limestone (D).
g = *Punctospirifer scabricosta* mut. *ashfellensis*, Carboniferous Limestone (S).
h = *Spiriferina multiplicata*, Permian.
j = *Spiriferina oxygona*, Lower Lias.

in that its lateral portions converge upwards between the primary lamellæ of the spires, and form a structure resembling an inverted **V**, instead of being a simple transverse loop as in the latter species.[2] This fact favours the separation here suggested, especially as the jugum of *Punctospirifer* is of a similar nature; while, in a specimen of *Sp. cristata* figured by H. B. Geinitz,[3] the jugum was like that of *Sp. rostrata*.

The Carboniferous shells are considerably smaller than those

[1] See Girty [9] pp. 371–72. [2] Hall & Clarke [14] p. 54.
[3] 'Dyas oder Zechsteinformation & das Rothliegende' 1861, pl. xvi, fig. 2.

from the Lias, and the Permian shells in this country are smaller than either. The small size of the Permian specimens is doubtless due to the unfavourable conditions under which they lived; while the large size of the Liassic species is in keeping with the fact that the race was nearing extinction.

Although there is every reason for believing that such is the case, it is not here definitely asserted that the Permian and Liassic species mentioned are homogenetic with the Carboniferous species cited as examples of the two types. A discussion of the post-Carboniferous forms must be deferred, until it has been possible to examine the holotypes (where they still exist) or topotypes of the species concerned.

The whole series of laminose Spiriferids affords an interesting example of the conditions referred to by the late Dr. Ivor Thomas when discussing the Productids[1]:—

'It is becoming more and more recognized that possession of similar features alone may be misleading and an insufficient criterion for the estimation of species. Externally the individuals may be morphologically almost indistinguishable, and yet belong to totally different lines of development and therefore to different genera.'

(*b*) Punctospirifer, gen. nov.

Description.—Shell spiriferoid, about twice as wide as long, greatest width at or near the hinge-line; cardinal extremities slightly rounded or subangular; area moderately high and concave.

Pedicle-valve subpyramidal, lateral slopes evenly convex, mesial sinus wide and shallow; beak small, pointed, and slightly incurved.

Brachial valve convex; mesial fold well developed, rounded, distinctly raised above the general level of the valve, and about as wide at the anterior margin as three of the adjacent costæ and the furrows separating them.

Lateral slopes of both valves ornamented by rounded costæ, separated by rounded furrows, about equal to them in width.

Surface of both valves crossed by regularly-disposed imbricating lamellæ, which in adult specimens may be more or less obsolescent, especially in the posterior portion of the valve.

Shell-structure fibrous and strongly punctate.

Internal structures:—Pedicle-valve.—Delthyrial supporting-plates slightly divergent: median septum well developed, thickened at its base, and near the beak extending about two-thirds of the distance from the floor of the valve to the area; it terminates somewhat abruptly about half-way towards the anterior margin. There is no marked development of an apical callosity, so that the three vertical septa appear as distinct structures in sections quite near to the beak.

Brachial valve.—A low median crest bisects the muscular scars; the spiral coils are large, and have their apices directed

[1] 'British Carboniferous Producti' Mem. Geol. Surv.: Palæontology, vol. i, pt. 4, p. 253.

laterally to a point a little anterior to the cardinal extremities; the jugum is slender, and forms a shallow V-shaped process, with its apex directed ventrally and posteriorly.[1]

Range.—(As at present determined) Carboniferous Limestone.[2]

Genotype.—*P. scabricosta*, sp. nov.

Remarks.—This genus differs from *Spiriferina* in the greater number of its costæ, which are smaller and less angular, in the greater relative size of its fold and sinus, and in its jugum. From *Tylothyris* it differs in its punctate shell-substance, and in the absence of a well-developed apical callosity.

PUNCTOSPIRIFER SCABRICOSTA, sp. nov. (Text-figs. 1 *p*, 4 *h*, 5 *f*, & 5 *g*, pp. 166, 199, 211; Pl. XIII, fig. 6.)

1912. *Spiriferina laminosa* (M'Coy), Garwood [13] p. 572 & pl. li, figs. 7*a*–7*e*.

Description.—Shell spiriferoid, of medium size, greatest width a little below the hinge-line.

Pedicle-valve subpyramidal, cardinal area about a third as high as wide; concave, especially towards the beak which is small and pointed; apical angle about 110°, delthyrial angle 40°; sinus shallow (width about three times the depth).

Brachial valve convex, median fold narrow at the beak, rounded, and strongly defined anteriorly.

Each lateral slope in both valves bears from seven to ten simple rounded costæ, separated by rounded furrows, and crossed by a strong concentric lamellar ornament.

Internal structures:—Pedicle-valve. Delthyrial supporting-plates attached to the floor of the valve for about a third of its length; median septum attached to the floor of the valve for half its length, thickened at the base, and tapering rapidly upwards; no apical callosity.

The dimensions of an average specimen are—width along hinge-line, 20 mm.; length of brachial valve, 12 mm.; height of area, 10 mm.

Holotype.—A specimen from the Ashfell Sandstone (lower part of the *Productus-corrugato-hemisphericus* Zone, S) of the Ravenstonedale district, in the collection of Prof. E. J. Garwood; figured, Q. J. G. S. vol. lxviii (1912) pl. li, figs. 7 *a*–7 *e*.

Comparison with *Tylothyris laminosa*.—The more obvious differences between this species and *T. laminosa* (namely, the punctate shell-structure and the absence of an apical callosity) have already been mentioned. It is further distinguished by the fact that the shells are usually much smaller than the representatives of *T. laminosa* and *T. subconica*, which occur in the Upper Avonian strata.

[1] The jugum as seen in a specimen rubbed down for the purpose is strikingly similar to, but rather less angular than, that described by Hall & Clarke [14] p. 54, as occurring in *Spiriferina kentuckyensis*, which in external appearance also has much in common with the genus under consideration.

[2] But it is highly probable that the genus includes species in Permian and even later formations.

Mutations of *Punctospirifer scabricosta.*

P. scabricosta is typically developed in the Upper Avonian of the North of England. It is found in the *Productus-corrugato-hemisphericus* Zone of Westmorland, and in beds of *Dibunophyllum* age in Northumberland. The forms characteristic of those two horizons possess certain distinctive features. The differences between them are not sufficient to warrant specific separation: but the later type is undoubtedly a time-variant of that which occurs at the lower horizon, and they may be conveniently considered as mutations of one species.

(1) P. SCABRICOSTA, mut. ASHFELLENSIS. (See text-fig. 5 *g*, p. 211.)

Example.—The holotype of *P. scabricosta.*

Horizon.—*Productus-corrugato-hemisphericus* Zone (S) of the Kirkby-Stephen and Ravenstonedale districts, where it is found in the Ashfell Sandstone in the lower part of that zone, and in the 'Bryozoa-Band' at the top of the zone (S_2).

(2) P. SCABRICOSTA, mut. REDESDALENSIS. (See text-fig. 5 *f*, p. 211; Pl. XIII, fig. 6.)

Examples.—Specimens described by King, Davidson, and others, as *Spirifera laminosa*.[1]

Horizon.—Bernician (D_1, Redesdale Beds) of Redesdale, etc. (Northumberland).

These two mutations differ in external features. The mut. *ashfellensis* approximates most closely to the specific characters already given; mut. *redesdalensis* differs from it in the following respects:—

(1) The area is a little less elevated, its height being about a quarter of the width, instead of two-fifths, as in mut. *ashfellensis*.

(2) The fold in the brachial valve is less elevated, and the sinus in the pedicle-valve shallower.

(3) The costæ are rather more numerous and narrower, there being about nine or ten on each lateral slope, instead of only seven or eight, as in the earlier mutation.

(*c*) Carboniferous Species of *Spiriferina*.

Forms still retained in *Spiriferina* occur throughout the Carboniferous Limestone, from the *Cleistopora* Zone to the *Dibunophyllum* Zone; they reach their acme in the Upper *Dibunophyllum* Zone, where they include *Spiriferina insculpta* (Phillips), *Sp. octoplicata* (J. de C. Sowerby), and *Sp. perplicata*, sp. nov., species which differ in the number and intensity of their plications.

Early mutations of the mature forms occur at lower horizons, but they are not common, and have not hitherto been satisfactorily classified. The general tendency has been to refer to them all as

[1] King [17]; Davidson [4] p. 37.

Spiriferina cf. *octoplicata*; while Vaughan compared certain of them with the Belgian species, *Sp. peracuta* De Koninck.

Since the three species mentioned are most typically developed in the *Dibunophyllum* Zone, and the holotypes of the species already described (namely, *octoplicata* and *insculpta*) were obtained from beds of that age, it seems desirable to select a form from that horizon as the holotype of the new species *perplicata*, and to deal first with the three species as typically developed, before discussing their earlier mutations.

Spiriferina octoplicata (J. de C. Sowerby). (Text-figs. 4 *g* & 5 *b*, pp. 199, 211; Pl. XIII, figs. 8 & 9.)

1827. *Spirifer octoplicatus* J. de C. Sowerby [32] p. 120, & pl. dlxii, figs. 2–3, *non* fig. 4.
1844. *Spirifer cristatus* M'Coy [20] p. 133.
1859. *Spiriferina cristata*, var. *octoplicata* Davidson [4] p. 38 & pl. vii, figs. 37–47 (probably only figs. 38–41 really belong to this species).
1915. *Spiriferina octoplicata* (Sowerby), Vaughan [35] pl. iii.

The original description is as follows:—

'Transversely elongated, gibbose, semicircular, plaited; plaits 8 or 10, deep and angular; central elevation plain; beaks remote, incurved; area triangular, curved.'

Description.—Shell small, transverse, cardinal extremities slightly rounded. The dimensions of a specimen of average size are: width along hinge-line, 20 mm.; length, 10 mm.; thickness, 8 mm. The area of the pedicle-valve is concave, the curvature increasing towards the beak; it is defined by a pair of lines diverging from the apex, and gradually curves over into the lateral slopes. The beak of the pedicle-valve is small, pointed and incurved, and that of the brachial valve is tumid and incurved.

Both valves are markedly and almost equally convex. The mesial fold is angular, but is frequently flattened anteriorly; the mesial sinus is also angular, and is sharply defined by a pair of angular costæ originating at the beak. The lateral slopes of each valve are ornamented by about four angular costæ: those on either side of the median fold are rather more than half as wide as the fold, and the remainder are progressively smaller. The costæ are separated by deep angular furrows. Of the costæ in the brachial valve, only three on each side of the fold originate at the beak, so that in small immature specimens each lateral slope has but three costæ. Median septum in the pedicle-valve attached to the floor of the valve for about a third of its width, thick at the base, it rapidly tapers and becomes knife-like; near the beak it rises about half-way to the level of the area, and becomes gradually lower anteriorly. Its posterior portion is embedded in a slightly-developed apical callosity.

Surface of the shell marked by a few concentric lamellæ which, like those in *Sp. walcotti*, are widely spaced, and occur chiefly in the anterior region. The flaking-away of the external layers often leaves the surface of the shell smooth, and is responsible for the characteristic appearance of many of the Derbyshire specimens.

Sowerby's types are preserved in the British Museum (Natural History) and typical specimens are excellently illustrated in Vaughan's 'Belgian paper' (pl. iii).

Horizon and localities.—Carboniferous Limestone (K–D); (of the mature form, that is, the holotype, D_2–D_3; locality, Derbyshire). In this country the mature form has not been found south of the Midland area, but Vaughan records its occurrence at Visé.[1]

Remarks.—Davidson and M'Coy have included in this species several forms which obviously do not belong to it, and as a result, the descriptions given by both those authors are misleading. M'Coy [2] describes it as having five or six cord-like 'ribs' on each lateral slope, a 'midrib' as wide at the margin as three lateral ones, and a surface covered with coarse scale-like laminæ of growth. He gave no figure, but he was probably referring to a form like that figured by Davidson [4] pl. vii, fig. 37. In a previous work, however, M'Coy stated that *Sp. octoplicata* had four large angular 'ribs' on each side of the mesial ridge, and a smooth surface.[3] None of Davidson's figures adequately depict the typical mature form of this species. Those which approach nearest to it are pl. vii, figs. 38–41, said to be from Sowerby's original examples.

This uncertainty as to the precise significance of the name *octoplicata* is probably in part to be attributed to the fact that one of Sowerby's figures (fig. 4) differs considerably from the other two. There can, however, be no doubt as to which of the two forms Sowerby himself regarded as the type of his species, for he suggested that the specimen illustrated in fig. 4, which possessed certain special characters, might prove to belong to another species.

Of the two specimens figured by Davidson [4] from 'Lough Hill' (Sligo),[5] one, fig. 47, belongs to this species; while the other, figs. 42–44, more closely approaches *Spiriferina perplicata*.

The desirability of separating this species from the Permian *Sp. cristata* Schlotheim, has been discussed by Davidson, King, L. G. de Koninck, and others, but owing to the uncertainty as to the exact significance of either name, the opinions expressed were at variance. As, however, the name *cristata* was originally applied to a vaguely-defined Permian shell, it seems desirable to regard the two species as distinct, although it is highly probable that from *Sp. octoplicata* descended some of the Permian Spiriferinas referred to *cristata*. In the extent of the development of the ventral median septum, *Sp. cristata* is intermediate between the Carboniferous and the Liassic species.

[1] Vaughan [35] p. 45.

[2] M'Coy [21] p. 18.

[3] M'Coy [20] p. 133.

[4] Davidson [4] pl. vii, figs. 42, 44, & 47. These specimens are now in the Museum of Practical Geology (Geological Society Collection). That illustrated in fig. 47 bears the Register No. 5705 A, while on the same tablet is that illustrated in figs. 42–44, together with a similar specimen not figured.

[5] Prof. G. A. J. Cole suggests that this must be a misprint for Lough Gill. *(In litteris.)*

Mutations of *Spiriferina octoplicata.*

1. SPIRIFERINA OCTOPLICATA, mut. D. (Pl. XIII, fig. 8.)

This mutation is the typical *Dibunophyllum*-Zone form already described, and represented by Sowerby's type-specimens.

2. SPIRIFERINA OCTOPLICATA, mut. δ, Vaughan. (Pl. XIII, fig. 9.)

This is a small form possessing all the essential characters of the later mutation, somewhat less highly developed.

The area is lower, and the valves less convex than in the typical form, than which, in consequence, the shell has a less inflated appearance. It also differs from the later mutation, in that the costæ are less angular and are separated by shallower furrows, while the concentric ornament is more regularly developed.

Horizons and localities.—Middle Avonian, Horizons γ to δ, in the South-Western Province.

Remarks.—This mutation is the form defined by Vaughan [1] as *Sp. octoplicata*, mut. δ. It differs from *Sp. insculpta* in the number and size of its costæ, which in the latter species are fewer in number and larger in size. *Sp. insculpta*, moreover, occurs at a higher horizon.

It is readily distinguished from the Lower Avonian mutation of *Sp. perplicata* which has five or six costæ on each lateral slope.

SPIRIFERINA INSCULPTA (Phillips). (Text-figs. 4*f* & 5*a*, pp. 199, 211; Pl. XIII, fig. 11.)

1836. *Spirifera insculpta* Phillips [27] p. 216 & pl. ix, figs. 2–3.
1844. *Spirifera quinqueloba* M'Coy [20] p. 134 & pl. xxii, fig. 7.

The original description is as follows :—

'*Spirifera insculpta.* Bolland, Derbyshire. Cardinal area large; the mesial and two or three lateral folds very bold, acute, and strongly striated across.'

Although the holotype of this species, which is now in the British Museum (Natural History) Geological Department, Gilbertson Collection, B 304, is fairly well depicted in Phillips's figures, the name has been used in a loose way for small strongly-plicated Spiriferoid shells from Devonian as well as from Carboniferous rocks. Davidson's figures of the original specimen [2] are somewhat misleading, and convey the impression that the shell is more elongate than is actually the case.

The holotype is a large (for the species) mature specimen, and is readily distinguished from adult specimens of *Sp. octoplicata*, although the differences between young individuals of those two species are less obvious.

The essential characters of the species are as follows :—Shell spiriferoid; moderately-high curved area; beaks small, but well developed, and incurved in the pedicle-valve, prominent and incurved in the brachial valve. The cardinal extremities are rounded.

[1] Vaughan [35] p. 45.
[2] Davidson [4] pl. vii, figs. 52–55.

In the brachial valve there are, on each side of the angular fold, three lateral costæ; the first of these is nearly as large as the fold, but the others decrease rapidly in size. In the pedicle-valve, including those bounding the sinus, there are three costæ on each lateral slope. The fold, the sinus, and the costæ are sharply angular, and the latter are separated by deep angular furrows about as wide as the costæ. The surface of both valves, except the cardinal area, is covered by strongly-imbricating lamellæ, especially distinct anteriorly. The shell-substance is strongly and coarsely punctate.

Nothing is known of the internal structures, beyond the fact that there is a median septum in the pedicle-valve, like that in *Spiriferina octoplicata*.

The dimensions of an average specimen are as follows: width along the hinge-line, 14 mm.; length of brachial valve, 9 mm.

Remarks.—Small immature specimens have a lower area, and are less tumid; but the small number of prominent costæ, the deeply-serrated anterior margin, and the strong lamellar ornamentation enable them to be readily identified: although, since the outer lateral costæ commence at some little distance from the beak, there are, in young shells, only two lateral costæ on each side, and these are somewhat less angular than in the adult.

Under some conditions of preservation the external shell-layers are lost, and the surface appears to be smooth; the punctæ are then very distinct. The immature form is well illustrated by a small specimen B 20570, from Gwyn, Llanfair (Anglesey), in the Geological Department of the British Museum (Natural History), and by some of Davidson's figures, as, for instance, [4] pl. lii, figs. 14 & 15.

Sp. quinqueloba of M'Coy was, in all probability, a small, but not typical, example of this species.

Sp. insculpta may be distinguished from *Sp. octoplicata* by the small number of the costæ and the deeper furrows separating them; by the more uniform distribution of a strong lamellar ornament; and by its general shape. The hinge-line of *insculpta* is relatively shorter than that of *octoplicata*, so that in the former species the shell tends to be rotund, while in the latter it is distinctly elongated.

Horizons and localities.—Upper Avonian (especially D_2) in the Midlands and Yorkshire, as, for example, Parkhill, Wetton, Settle. It is last recorded from the Upper *Posidonomya* Beds of Loughshinny, where it is represented by a typical specimen figured by Vaughan.[1] None of the Lower Avonian Spiriferinæ from the South-Western Province appear to belong to this species; but the name has been applied to small highly-plicated Spiriferids occurring in the Devonian rocks.[2] In these, however, the shell-substance is impunctate, and they are, in all probability, representatives of the

[1] Vaughan [24] pl. l, fig. 9.

[2] G. F. Whidborne, 'A Monograph of the Devonian Fossils of the South of England' Pal. Soc. vol. ii (1892-97) pp. 109–10.

Silurian genus *Delthyris* (for instance, *D. elevata*); but, whether this is a case of homœomorphy, or whether the Silurian and Carboniferous species are genetically connected by a gradual transition during Devonian times to the punctate condition seen in the Carboniferous shells, cannot at present be determined.

SPIRIFERINA PERPLICATA, sp. nov. (Text-fig. 5 *c*, p. 211; Pl. XIII, figs. 7 *a*–7 *c* & 10.)

Description.—Shell spiriferoid, of medium size, greatest width at the hinge-line, cardinal extremities nearly right angles, or slightly produced.

Pedicle-valve subpyramidal; cardinal area well defined, about a third as high as wide, flat near the hinge-line, but concave towards the beak, which is small and pointed; apical angle 120°; delthyrial angle 40°; lateral slopes tumid and evenly convex; sinus angular, about twice as wide as deep.

Brachial valve evenly convex, mesial fold angular, and about as wide at the margin as two of the adjacent costæ and the furrow between them.

Each lateral slope in both valves bears about six angular costæ, separated by equally angular furrows slightly narrower than the costæ.

Surface of both valves, except the area, crossed by concentric scale-like laminæ, not evenly distributed over the surface of the shell. Shell-substance coarsely punctate.

Delthyrial supporting-plates and median septum as in *Sp. octoplicata.*

The dimensions of an average specimen are as follows:—Width along hinge-line, 22 mm.; length of brachial valve, 10 mm.; height of area, 6 mm.

Holotype.—A specimen in the collection of Mr. J. W. Jackson, F.G.S., of Manchester (figured in Pl. XIII, figs. 7 *a*–7 *c*).

Horizons and localities.—Carboniferous Limestone; of the holotype, Upper *Dibunophyllum* Zone, Peak's Hill. The typical form occurs only in the *Dibunophyllum* Zone.

Comparison with *Sp. octoplicata*, etc.—This species differs from *Sp. octoplicata* in having a more clearly defined and less curved area, and in the greater number of its costæ, which are separated by narrower and shallower furrows than in that species.

From both *Tylothyris laminosa* and *Punctospirifer scabricosta* it differs in the relative uniformity of the size of its costæ and the fold in the brachial valve, and it may be further distinguished from the former species by its punctate shell-structure.

One of the specimens figured by Sowerby as *Spirifer octoplicata*, namely [32] pl. dlxii, fig. 4, and refigured by Davidson,[1] in all probability belongs to this species, although its fold is of an exceptional character, being divided anteriorly into three by two short furrows.[1]

[1] Davidson [4] pl. vii, fig. 37; pl. lii, fig. 13. The original specimen is distorted, and Davidson's figures are idealized.

Mutations of *Spiriferina perplicata.*

1. Spiriferina perplicata, mut. D.

This is the form represented by the holotype of the species (Pl. XIII, figs. 7 *a*–7 *c*).

2. Spiriferina perplicata, mut. K. (Pl. XIII, fig. 10.)

1905. *Spiriferina* cf. *octoplicata* Vaughan, 'Bristol Paper' [33] pl. xxvi, fig. 6; and 'Burrington Paper' [28] p. 384.
1915. *Spiriferina octoplicata* mut. K, Vaughan, 'Belgian Paper' [35] p. 44 & pl. vii, fig. 1.

This mutation has all the essential characters of the species, as already enumerated, but it differs from the typical (D) form in the following respects:—The cardinal area is lower and the brachial valve less convex; the shell is, in consequence, less gibbose.

Pedicle-valve.—The beak is more sharply incurved; the costæ on either side of the sinus are rather more conspicuous than the lateral costæ, so that the sinus is sharply defined; this character is still noticeable, although less obvious in the later mutation.

Brachial valve.—The fold is slightly flattened anteriorly, and the costæ are separated by somewhat shallower furrows.

Horizons and localities.—In the South-Western Province this mutation occurs in the *Cleistopora* Zone and at Horizon β. In the Avon Section it reaches its acme at the top of K_2, but in the Burrington Section it is rare at that horizon: at Mitcheldean it occurs in K.

Remarks.—This mutation is the form cited by Vaughan as *Spiriferina* cf. *octoplicata* in his earlier (that is, 'Bristol' and 'Burrington') papers, and as *Sp. octoplicata* mut. K in his 'Belgian Paper.' In the 'Burrington Paper' (pp. 384–85), he also compares it to *Sp. peracuta* De Koninck, which is abundant in Z_1 of Belgium. In the absence of an examination of the type-specimen of *Sp. peracuta*, a comparison between that species and the form under discussion is not possible; but, judging from De Koninck's [1] and Vaughan's [2] figures of typical specimens, the two are distinct, *Sp. perplicata* having more costæ and a relatively-larger median fold than the other form. In any case, this does not affect the conclusion arrived at concerning the relationship of *Sp. perplicata* mut. K, because, even if it should eventually prove to be identical with De Koninck's species, it would still be the Lower Avonian representative of *Sp. perplicata*.

The two following forms figured by Portlock probably belong to this species:—

(1) The obscure specimen described as *Spirifera partita*,[3] and now in the Museum of Practical Geology (Reg. No. 28427). Owing to its

[1] Ann. Mus. Roy. Hist. Nat. Belg. vol. xiv, pt. 6 (1887) pl. xxii, figs. 56–61.

[2] Vaughan [35] pl. vii, fig. 2.

[3] J. Portlock, 'Geol. Rep. Londonderry, &c.' 1843, p. 567 & pl. xxxviii, fig. 3; see also Davidson [4] pl. vii, figs. 60–61.

imperfect nature and state of preservation, the affinities of the specimen cannot with certainty be determined. The locality of the figured specimen is given as Kildress (Tyrone).

2. A specimen described as 'near to' *octoplicata*, but having more costæ than that form[1]: in this case, however, the specimen does not appear to have been preserved.

Additional Note upon *Spiriferina*.

It is, perhaps, scarcely necessary to mention that, although the three Carboniferous species of *Spiriferina* enumerated can be readily recognized even in their early mutations, as well as in their mature condition, there are no hard-and-fast lines of distinction between them. Regarded as a whole and as members of a genus, they are sharply differentiated from contemporary forms, and are an interesting example of evolution in a 'sheaf of parallel forms.'[2]

The young stage (in a phylogenetic sense), with small and simple forms, occurs in the Lower Avonian, and the adult stage, in which the full size was reached and the essential characters fully developed, was attained in *Dibunophyllum* times.

There are other forms which represent species additional to those enumerated here, but they are less common, and a discussion of their characters is reserved for a future paper.

VII. Summary of Conclusions.

1. The special characters of *Syringothyris* were first described by L. G. de Koninck in a Belgian specimen wrongly identified as *Spirifer distans*. The name *Syringothyris* was proposed by A. Winchell, who discovered in a North American Carboniferous shell, characters similar to those already noticed by De Koninck. The existence of the syrinx in *S. cuspidata* (Martin) was first recorded by F. B. Meek.

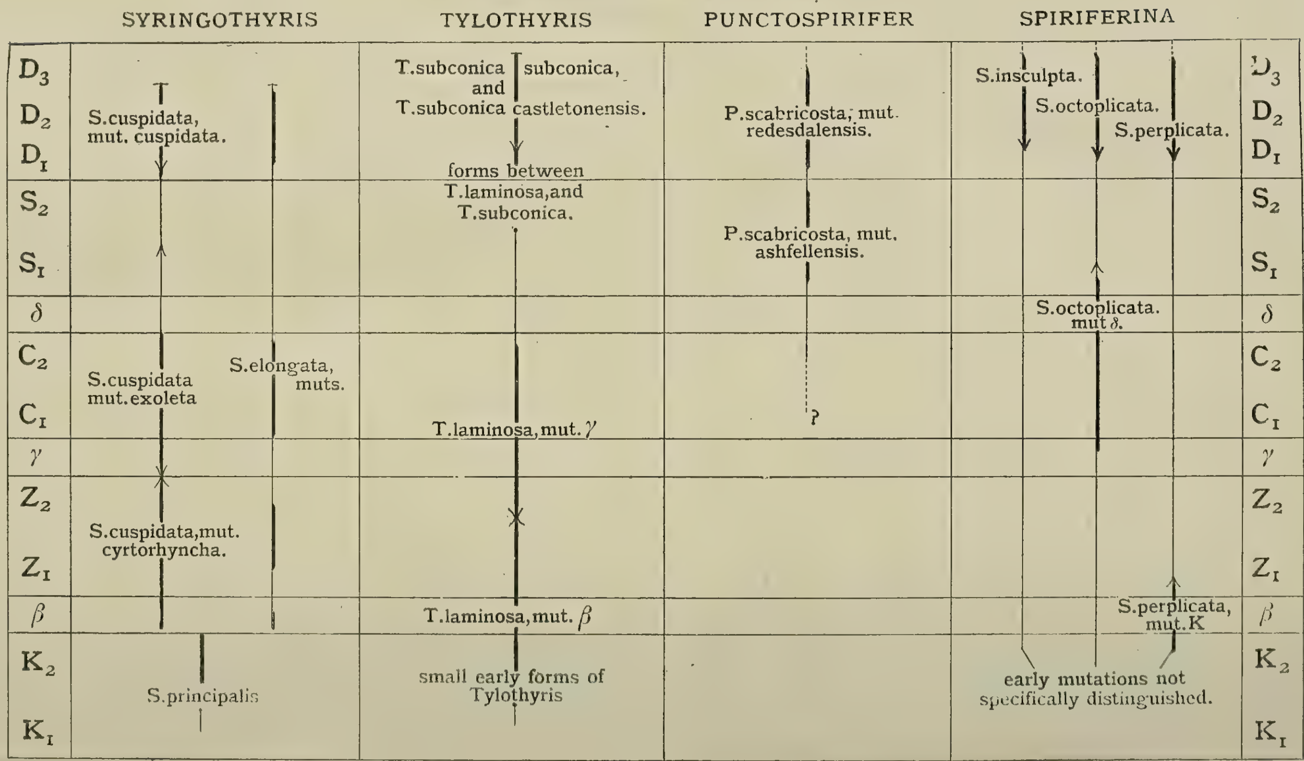
2. The essential characters of the genus are:—its strongly cuspidate outline, a fold and sinus devoid of plications, an imperforate deltidium, a finely and sparsely punctate shell-substance, and a syrinx-bearing transverse plate between the delthyrial supporting-plates.

3. The satisfactory classification of the forms included in the genus is a matter of some difficulty, owing to the nature of the variations which occur. Variations due to time, to environmental conditions, and to distribution in space are recognized; and distinctive names are given to the mutations characteristic of certain horizons.

4. The syrinx and the transverse plate to which it was attached originated as a modification of an apical callosity such as existed in many Spiriferoid shells. It was initiated in Middle Devonian

[1] J. Portlock, *ibid.*, pl. xxxviii, fig. 8.
[2] See, for example, Vaughan [35] p. 3.

Fig. 6.—*Synoptic table of the distribution of* Syringothyris, Tylothyris, Punctospirifer, *and* Spiriferina *in Avonian times.*



times, and reached its acme early in the Carboniferous Period. Our knowledge of the pre-Carboniferous history of the genus is, up to the present, derived entirely from its North American representatives.

5. In all known species of *Syringothyris* the fold in the brachial valve and the sinus in the pedicle-valve are smooth. Species such as *Spirifer distans*, in which the fold and sinus are plicated, do not possess a syrinx, and have been incorrectly referred to *Syringothyris*. The genus *Syringopleura*, founded to include shells with the internal characters of *Syringothyris*, accompanied by a plicated fold and sinus, is not valid, since the type-species *S. randalli* was imperfectly described, and the syntypes include two distinct forms: of these, those in which the fold and sinus were plicated do not possess the internal characters of *Syringothyris*.

6. The form referred to by M'Coy as *Spirifera laminosa*, which has also been regarded as belonging to *Cyrtia*, *Spiriferina*, and *Syringothyris*, is here assigned to a new genus, *Tylothyris*, since it has not the punctate shell-structure of *Spiriferina*, nor the internal characters of *Syringothyris*. The essential characters of *Tylothyris* are: a laminose surface-ornament, impunctate shell-substance, a ventral median septum, and a peculiarly developed apical callosity. The genus is represented in the Lower Avonian by mutations of *T. laminosa* (M'Coy), and in the Upper Avonian by subspecies of *T. subconica* (Martin).

7. *Syringothyris* and *Spiriferina* are in no way related, either morphologically or phylogenetically.

8. The small Carboniferous shells with a punctate shell-structure, laminose surface-ornament, and a ventral median septum, which have hitherto been referred to *Spiriferina*, include two types characterized by external differences and by slight variations in the jugum. Of these two types, one, in which there are numerous costæ and a relatively-large rounded fold and sinus, is relegated to a new genus, *Punctospirifer*; while the members of the other type, which include shells with a few large angular costæ but little smaller than the angular fold and sinus, are, for the present at least, retained in *Spiriferina*, although the type-species of that genus is a Liassic form. Both of these types belong to the family Suessiidæ which is represented also in Permian and Triassic rocks. The subdivision here suggested for the Carboniferous forms will, it is believed, prove to be applicable to the later species also. The investigation of these forms, and of the relation, if any, which exists between them and the Devonian and Silurian species which resemble them in all but the punctate shell-structure, is not yet completed.

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EXPLANATION OF PLATES XI–XIII.[1]

[All figures are of the natural size, unless otherwise indicated.]

Plate XI.

Fig. 1. *Syringothyris principalis*, sp. nov. Pedicle-valve. K zone; Trot's Corner, Mendip area. (Coll. of Principal T. F. Sibly, 20474 G 1.)[2]

2. *Syringothyris principalis*, sp. nov. Pedicle-valve. K_2 subzone; Howle Hill, Mitcheldean district. (Coll. of Principal T. F. Sibly, 20474 G 2.)

3. *Syringothyris cuspidata*, mut. *cyrtorhyncha*. (*a*) Brachial valve; (*b*) profile. Z_1 subzone; Avon Section (south side), Bristol. (Coll. by the writer, now in the National Museum of Wales. Reg. No. 19246 G 2.)

4. *Syringothyris cuspidata*, mut. *exoleta*. (*a*) Brachial valve; (*b*) profile. C_2 subzone; Black Rocks, near Sutton (Glamorgan). (Coll. of Principal T. F. Sibly, 20474 G 3.)

5. *Syringothyris cuspidata*, mut. *exoleta*. Waulsortian 'knoll'-type. (*a*) Brachial valve; (*b*) profile. C zone; Momane (Limerick). (Coll. of the Geological Survey of Ireland. No. 1142. Figured by permission of the Director.)

6. *Syringothyris cuspidata*, mut. *cyrtorhyncha*. Internal cast of the pedicle-valve, showing the infilling of the syrinx and its slit. Z zone; Mitcheldean Quarry (Gloucestershire). (Coll. of Principal T. F. Sibly, 20474 G 4.)

7. *Syringothyris cuspidata*, mut. *cuspidata*. Specimen with asymmetric area (pedicle-valve, looking towards the apex). Upper Avonian; Ell Bolton, Cracoe (Yorkshire). (Coll. by the late Dr. Wheelton Hind.)

8. *Syringothyris cuspidata*, mut. *cuspidata*. Pedicle-valve, looking towards the apex. D_2 subzone; Castleton (Derbyshire). (Coll. by the late Dr. Wheelton Hind.)

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[1] The cost of the drawings from which these Plates and other illustrations are reproduced has been defrayed by a grant from the Dixon Fund of the University of London.

[2] Principal Sibly has now presented to the National Museum of Wales, Cardiff, all his specimens that have been figured or mentioned in this paper, and their registration-numbers are given above.

PLATE XII.

Fig. 1. *Syringothyris cuspidata*, mut. *cuspidata*. (*a*) Brachial valve; (*b*) profile. (The same as Pl. XI, fig. 8.) D_2 subzone; Castleton (Derbyshire). (Coll. by the late Dr. Wheelton Hind.)

2. *Syringothyris cuspidata*, mut. *cuspidata*, distorted specimen. (*a*) Profile; (*b*) brachial valve. D zone; Little Island (Cork). (Sedgwick Museum Coll., on Tablet 945.)

3. *Syringothyris elongata*, sp. nov. The area of the pedicle-valve, slightly crushed. Z zone; Malahide (County Dublin). (Geological Survey of Ireland Coll. Figured by permission of the Director.)

4. *Syringothyris elongata*, sp. nov. (*a*) The area of the pedicle-valve; (*b*) profile; (*c*) the brachial valve. C zone; Adare (Limerick). (Geological Survey of Ireland Coll. No. 1492. Figured by permission of the Director.)

5. *Syringothyris elongata*, sp. nov. (*a*) The area of the pedicle-valve; (*b*) brachial valve. D zone; Kniveton (Derbyshire). (Coll. by the late Dr. Wheelton Hind.)

PLATE XIII.

(NOTE.—Figs. 1-5 are from exfoliated specimens, and show no trace of the imbricate structure (fig. 16) seen in well-preserved examples of *Tylothyris*: such specimens are rare.)

Fig. 1. *Tylothyris laminosa*, mut. γ. Imperfect pedicle-valve. Z_2 subzone; Twyn-yr-odin (Glamorgan). (Coll. of Principal T. F. Sibly, 20474 G 5.)

2. *Tylothyris laminosa*, mut. γ. Brachial valve. Horizon γ; Alps Quarry, Wenvoe (Glamorgan). (Coll. by the writer, now in the National Museum of Wales. Reg. No. 19246 G 3.)

3. *Tylothyris subconica castletonensis*, subsp. nov. Brachial valve. D_2 subzone; Castleton (Derbyshire). (Coll. by the late Dr. Wheelton Hind.)

4. *Tylothyris subconica castletonensis*. (*a*) The area; (*b*) profile. D_2 subzone; Castleton (Derbyshire). (Coll. by the late Dr. Wheelton Hind.)

5. *Tylothyris subconica subconica* (Martin). (*a*) Brachial valve; (*b*) area; (*c*) profile. D_2 subzone; Settle (Yorkshire). (Sedgwick Museum Coll., Tablet 501.) [Fig. 5 *c* slightly exaggerates the curvature of the area: it is usually almost flat.]

6. *Punctospirifer scabricosta*, sp. nov., mut. *redesdalensis*. Brachial valve. D_1 subzone; Redesdale (Northumberland). (Coll. of Prof. E. J. Garwood.)

7. *Spiriferina perplicata*, sp. nov. (*a*) Brachial valve; (*b*) profile; (*c*) pedicle-valve. D_2 subzone; Treak Cliff, Castleton. (Coll. of Mr. J. W. Jackson, F.G.S., Manchester.)

8. *Spiriferina octoplicata*, mut. D (J. de C. Sowerby). Brachial valve. Parkhill (Derbyshire). (National Museum of Wales, 19246 G 10.)

9. *Spiriferina octoplicata*, mut. δ. Portion of brachial valve. Horizon γ; Little Island, Barry (Glamorgan). (Coll. of Principal T. F. Sibly, 20474 G 6.)

10. *Spiriferina perplicata*, mut. K. Brachial valve. K_2 subzone; Walton Castle, Clevedon (Somerset). (Coll. of Mr. J. W. Tutcher.)

11. *Spiriferina insculpta* (Phillips). D_2 subzone; Treak Cliff, Castleton. (Coll. of Mr. J. W. Jackson, F.G.S.)

12. *Tylothyris laminosa*, mut. γ. Cast of the interior of the pedicle-valve. C_1 subzone (*laminosa* dolomite); Collafield, north of Littledean (Gloucestershire). (Coll. of Principal T. F. Sibly, 20474 G 7.)

[November 30th, 1920.]

Fig. 13. *Tylothyris laminosa*, mut. γ. Interior of the pedicle-valve. Horizon γ; near Lavernock (Glamorgan). (Coll. of Principal T. F. Sibly, 20474 G 8.)

14. *Spiriferina walcotti* D'Orbigny. Internal cast of pedicle-valve. Lower Lias; Radstock (Somerset). (Coll. of the writer, now in the National Museum of Wales. Reg. No. 19246 G 9.)

15. *Tylothyris subconica subconica*. Interior of pedicle-valve. D_3 subzone; Waterhouses (Staffordshire). (Coll. of Principal T. F. Sibly, 20474 G 9.)

16. *Tylothyris laminosa* (M'Coy). Portion of the surface of a specimen retaining the imbricate structure, enlarged. Z zone; Hook Head (Wexford). (Coll. of Geological Survey, London. Reg. No. 28425.)

17. *Spirifer plicatosulcatus*, sp. nov. (*a*) Brachial valve; (*b*) the area. D, probably D_3 subzone; Beeston, near Waterhouses (Staffordshire). (Coll. of Geological Survey, London. Reg. No. 28422.)

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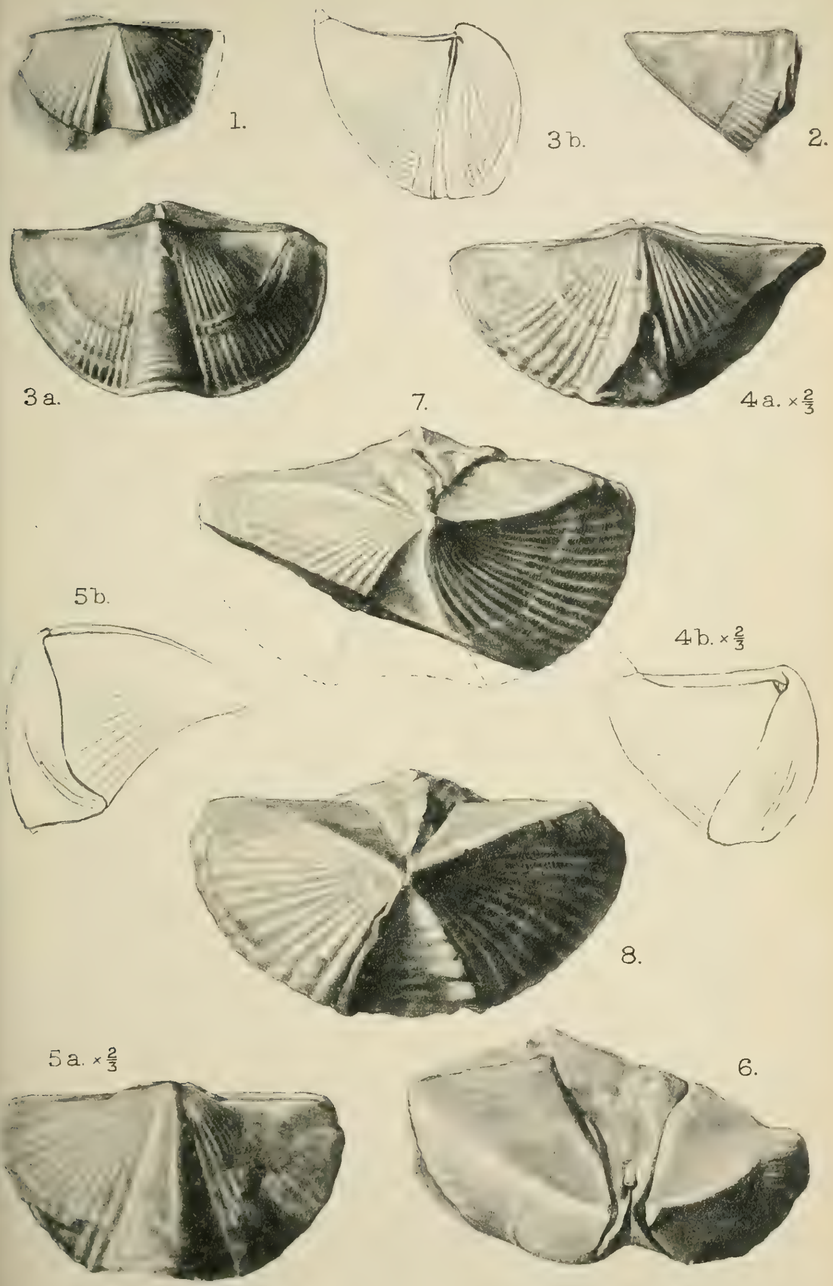
Dr. F. A. Bather congratulated the Author on the thoroughness of the methods used in his study. He had understood the Author to say that the forms of *Syringothyris* merged one into the other, and he enquired whether that statement referred to contemporaneous varieties and species, or to successive mutations. Was it possible to observe recapitulation of previous stages in the ontogeny of the later forms?

Principal T. F. Sibly welcomed this important contribution to Carboniferous palæontology, and expressed his appreciation of the value to zonal stratigraphy of the Author's careful and detailed researches.

The Author stated, in reply to Dr. Bather, that the variations of *Syringothyris* in a vertical sense were gradual and continuous, while at any one horizon forms belonging to either of the two species enumerated could be easily distinguished, when they occurred in normal deposits. Owing to the absence of suitable material, a study of recapitulation had not been possible.

In conclusion, the Author expressed his appreciation of the encouraging remarks made by the speakers in the Discussion, and thanked those who, by the loan of material, had made the work possible.



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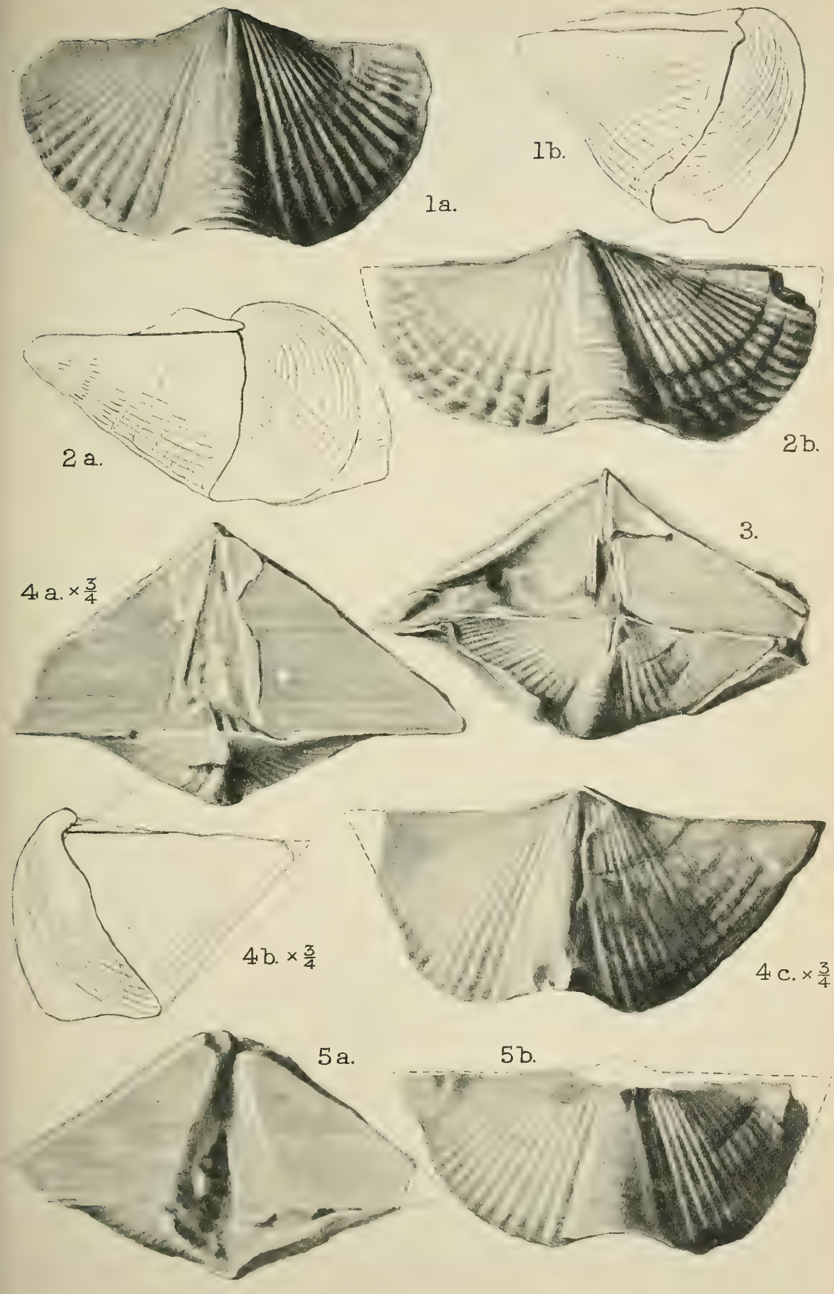
SYRINGOTHYRIS.



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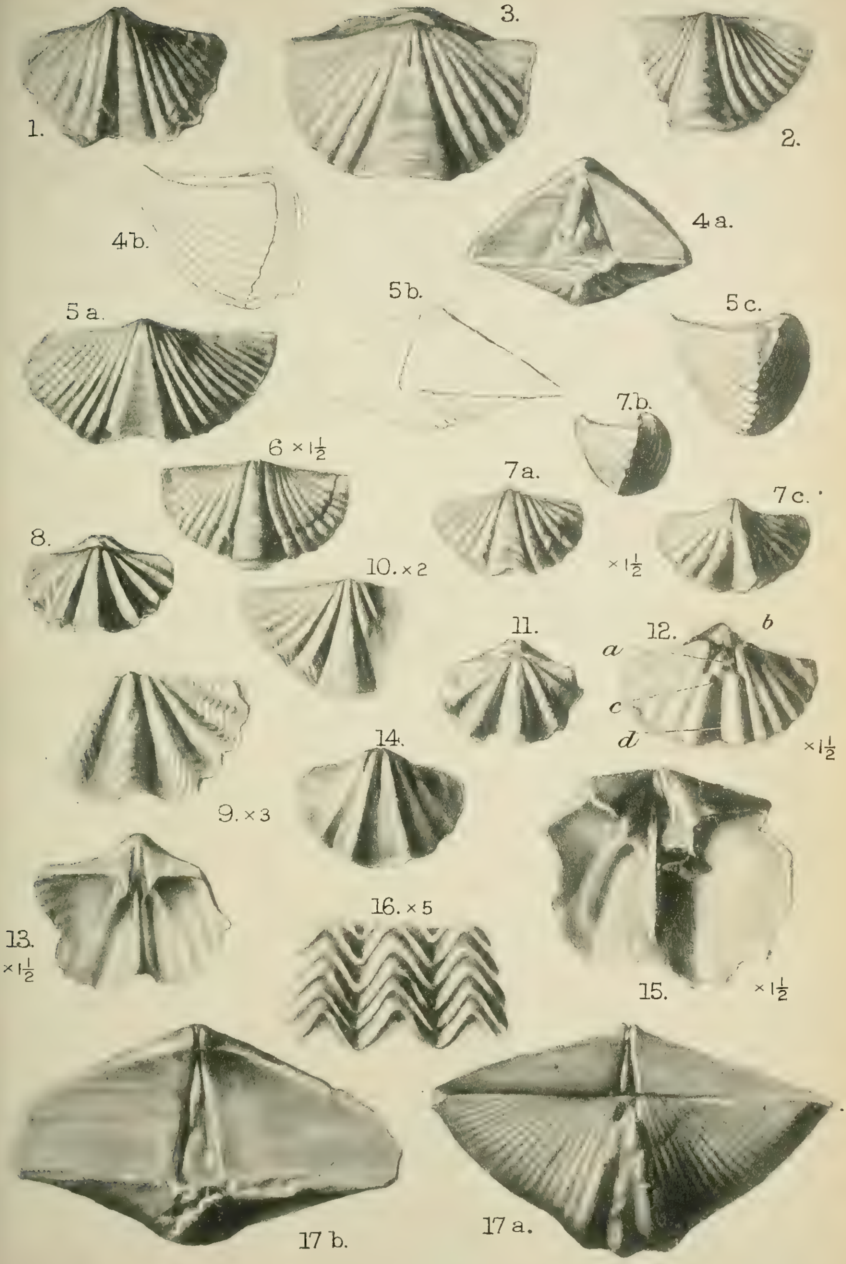

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TYLOTHYRIS, SPIRIFERINA, & SPIRIFER.

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CONTENTS.

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[The Editor of the Quarterly Journal is directed to make it known to the Public that the Authors alone are responsible for the facts and opinions contained in their respective Papers.]

*** The Council request that all communications intended for publication by the Society shall be clearly and legibly written on one side of the paper only, with proper references, and in all respects in fit condition for being at once placed in the Printer's hands. Unless this is done, it will be in the discretion of the Officers to return the communication to the Author for revision.

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Vol. LXXVI. No. 303.
Part 3.

THE

QUARTERLY JOURNAL

OF THE

GEOLOGICAL SOCIETY.

EDITED BY

THE PERMANENT SECRETARY.

[With Seven Plates, illustrating Papers by Mr. J. W. D. Robinson, Mr. S. H. Warren, and Prof. A. H. Cox & Mr. A. K. Wells.]

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ORDINARY MEETINGS OF THE GEOLOGICAL SOCIETY TO BE HELD AT BURLINGTON HOUSE.

Session 1920–1921.

1921.

Wednesday,	January	19*
,,	February (*Anniversary Meeting*, Friday, February 18th)	2*—23*
,,	March	9 —23*
,,	April	20*
,,	May	4 —25*
,,	June	8 —22*

[*Business will commence at 5.30 p.m. precisely.*]

The asterisks denote the dates on which the Council will meet.

Fig. 13. *Tylothyris laminosa*, mut. γ. Interior of the pedicle-valve. Horizon γ; near Lavernock (Glamorgan). (Coll. of Principal T. F. Sibly, 20474 G 8.)

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6. *The* Devonian *of* Ferques (Lower Boulonnais). By

John William Dudley Robinson, M.Sc., F.G.S. (Read April 21st, 1920.)

[Plate XIV—Map and Section.]

Introduction.

The Palæozoic rocks of the Boulonnais are classic ground, and received the attention, among others, of De Verneuil, Murchison, Rigaux, and above all Godwin-Austen and Gosselet. Owing to the occurrence of coal, however, most attention has been given to the Carboniferous deposits, and, except for palæontological work by Rigaux, the Devonian seems to have been comparatively neglected for the last forty years. The classic description is that published by Godwin-Austen in 1853, which has been slightly amended by Gosselet and Rigaux, while the beds have been correlated with those of other areas by Gosselet.

The published maps are poor, and of little use in the field. This is partly due to the lack of a good topographical map, but also to the apparent absence of detailed mapping. The accompanying map (Pl. XIV) suffers from the first defect, but was prepared on a scale of 1 : 1000 over an area extending across the outcrop along the Nord Railway, and on a scale of 1 : 10,000 for the remainder.

All the beds are referred to the Upper and to part of the Middle Devonian (Famennian, Frasnian, and Givetian). They consist of limestones, sandstones, shales, dolomites, and conglomerate.

Physical Aspect.

The Lower Boulonnais may be regarded as forming the southernmost extension of the Weald. It is ringed round by Chalk hills; but the denudation in the centre has been more extensive, exposing a considerable expanse of Jurassic rocks and a smaller one of the Palæozoic. The district is drained by a number of small streams, the courses of which were probably determined when the Cretaceous deposits extended over the whole area.

The country rises generally in a slight swell, from the base of the Chalk hills to the Devonian plateau; but the differences in level are slight, and the valleys shallow.

The Devonian rocks disappear under the Cretaceous on the north and east, under the Jurassic on the west, and are bounded by the Carboniferous on the south.

The soil is poor; some portions appear to have been recently brought under cultivation, but much is still covered by woods, rough commons with gorse and broom, and bogs.

A line of quarries stretches across the outcrop from end to end,

in one band of limestone; most of them are of ancient date, and have been opened for building-stone, especially large blocks for harbour-work and kerbing, and in the Middle Ages for fortifications. There are also a few isolated quarries. The shales are being worked for bricks, and the sandstones for rough paving, sills, etc.

Physical Structure.

Generally speaking, the beds consist of a number of parallel bands on the surface striking north-west and south-east, and this description has, up to the present, been accepted as sufficient. Detailed investigation, however, shows that they are intersected by a large number of dip-faults dividing the beds up into blocks (step-faulting). The strike of the beds is, therefore, actually more southerly than it appears to be from the general direction of the strata; the faulting gradually moves the beds in a northward direction towards the west. In addition, there are a number of subordinate strike-faults (thrust-faulting), while a major thrust-fault separates the Devonian from the Carboniferous. Former observers have described the Carboniferous as lying conformably on the Devonian,[1] or explain the absence of the uppermost Devonian strata by a cessation of deposition.

The general dip is south-westwards, varying from 20° to 45°, with an average of about 30°.

The limestones, sandstones, and dolomites usually project slightly above the general surface, forming small hills.

Lower Palæozoic beds (*Monograptus-colonus* Zone) have been found in a boring, a few hundred yards from the Devonian outcrop, at Caffiers, and in a shaft near the junction of the Mimoyecque and Paradis roads, but their relations are masked by the overlying Cretaceous rocks.

In addition to the main mass, there are smaller exposures at Hydrequent, Sainte Godeleine, and Rougefort; but, as the relations of these outcrops form a part of the problem of the Carboniferous deposits by which they are surrounded, they will not be considered here, except generally and with a view to the elucidation of doubtful questions relating to the main mass: they are regarded as being bounded in the main by faults, although their actual structure appears to require further consideration.

Palæontology.

No attempt is made in this paper to describe the palæontology in detail. Owing to incorrect interpretation of the structure, it is not always possible to ascertain in which bed specimens were found; the recorded forms are, therefore, of doubtful value in some cases.

[1] R. A. C. Godwin-Austen, Q. J. G. S. vol. ix (1853) p. 239.

Givetian.

Godwin-Austen describes[1] as the lowest beds a limestone (Limestone of La Cédule) with underlying black shales; from the former he obtained fossils in a quarry near La Cédule. Neither of these has since been seen. The fossils are the same as those that occur in the overlying Blacourt Limestone, and a reference to the map shows that a wedge of this limestone extends close to the north-west of La Cédule. There is no doubt that the quarry described was a small one, now overgrown, in this wedge. The shales probably belonged to the Gault.

Lower Givetian: Caffiers Conglomerate.—The lowest bed visible is a red conglomerate, consisting of big partly-rounded pebbles, embedded in clay or in a soft shale; in the upper part the pebbles are absent.

No fossils have been found. The beds may be seen in the railway-cutting south of Caffiers, and traced across the country to Blacourt by the colour imparted to the soil. There are also small exposures in the lanes north-east of La Cédule.

Caffiers Sandstone.—This can now only be seen in an old quarry north of Banc Noir Quarry, in the fields on the opposite side of the railway, in a path north-west of La Cédule, and in an old quarry by the road at Bainghen. Formerly a very complete section must have been visible in the railway-cutting as E. Rigaux[2] gives the section set out below. The exposures now seen are of a green fine-grained sandstone.

Some remains of plants have been found in these beds, and have been referred to *Rhodea condrusorum* and *Lepidodendron*.

			Feet	*inches.*
Caffiers Sandstone.	(*a*)	Greenish, yellowish, and red shales	32	10
	(*b*)	Sandstone	2	6
	(*c*)	Nodular limestone	4	11
	(*d*)	Fine-grained, greenish-grey, fissile sandstone	13	1
	(*e*)	Shales	4	11
	(*f*)	Sandstone as (*d*)	11	5
	(*g*)	Red and green shales	16	4
	(*h*)	Sandstone	11	5
	(*i*)	Grey shales	4	11
	(*j*)	Shaly sandstone and micaceous shales	16	4
Caffiers Conglomerate.	(*k*)	Red shales	45	11
	(*l*)	Red conglomerate	29	5

Middle and Upper Givetian: Blacourt Limestone.—This is a dark-grey to black massive limestone, about 840 feet thick. About 570 feet from the base the beds in places appear shaly, owing to strike-faulting. At the top the beds are shaly, but still calcareous. From the fossils the upper part is referred to the

[1] Q. J. G. S. vol. ix (1853) p. 242.

[2] 'Notice Géologique sur le Bas-Boulonnais' 1892, pp. 7–8.

Upper Givetian; but there is no petrological dividing-line. The Bastien Limestone described by Rigaux is the upper part of this limestone; but there are no shales between the two limestones, as he states. He has evidently been misled in the same way as Godwin-Austen, through not allowing for the shifting of the outcrops by the faulting.

The beds are well exposed almost right across the outcrop in Banc-Noir Quarry, and on the opposite side of the railway; there are also exposures in the Bastien Quarry on the west and in a small quarry between Blacourt and La Capelle near La Poussinerie. The upper beds are fossiliferous, where corals are common. The following fossils are recorded by Rigaux from this limestone (but further work is necessary in order to zone the beds):—

Athyris betencourti.	*Rhynchonella boloniensis.*
A. pelapayensis.	*Leptæna cedulæ.*
Atrypa aspera.	*Cyrtina heteroclyta.*
Spirifer urii.	*Stringocephalus burtini.*
Sp. orbelianus.	*Cyathophyllum boloniense.*
Sp. bouchardi.	*C. bouchardi.*
Sp. curvatus (?).	*Favosites dubia.*

Frasnian.

Shales of Beaulieu and Dolomites of Les Noces.—Part of these beds may, after zoning, prove to be more properly referable to the Givetian. They consist of three series of shales, two of dolomite and dolomitic limestone, surmounted by a group of thinly-bedded dolomite, as follows:—

		Feet.
Beaulieu Dolomite	Red and green marl with stone parting	5
	Green marl	2
	Yellow sandy dolomite	22
	Black sandy dolomite	5
	Yellow sandy dolomite	29
	Purple and green compact dolomite	13
Upper Beaulieu Shales.	Chocolate and green shales	115
Upper Les Noces Dolomite.	Red and yellow dolomite	112
Middle Beaulieu Shales.	Chocolate shales	60
Lower Les Noces Dolomite.	Red and yellow dolomite	105
Lower Beaulieu Shales.	Chocolate shales	120

The Beaulieu Shales are very constant in composition and of a uniform chocolate hue, except immediately under the sandstones and between the dolomites, where the shales are bright olive-green; they are seldom fossiliferous. The dolomites resemble each other closely, and are usually rough, sandy, and full of cavities. In places, they do not form continuous outcrops, but seem to have been built up as banks in the surrounding shales; all the exposures, however, fall into either the upper or the lower band. The series of shales have in a similar way been confused, owing to a tendency to ignore the faulting.

The Beaulieu dolomite has previously almost escaped notice as a separate bed, the black type and the green and purple type not

being recorded. The latter is a tough, compact, fine-grained rock; but the others are rubbly, sometimes being only loose sand. They are practically unfossiliferous; the black type, however, is full of white markings resembling worm-casts, and I have found one coral in the upper yellow bed.

The marls at the top are extremely fossiliferous, especially so immediately under the Ferques Limestone.

There are a number of small exposures of these deposits near Beaulieu Abbey, mainly in ditches. Elsewhere they are very rare, so far as the shales are concerned; but the dolomites can be traced across country as bare, dry, rocky hillocks.

Ferques Limestone.—This is a grey or blue-black massive limestone, very extensively quarried right across its outcrop from Fiennes Château to La Capelle. Corals and brachiopoda are abundant in the lower beds, and the upper beds which gradually become shaly and sandy are fossiliferous also; the massive middle beds too contain fossils, but they weather out less readily.

The middle beds have been most worked, owing to their greater thickness, the lowest being thinly stratified and the highest soft and shaly. Working has frequently ceased on a dip-fault being reached, owing to the clay and rubble in the fault-rock; in some cases the fault-rock is left standing as a wall. The thickness is 201 feet.

The following fossils are recorded by Rigaux ('Notice Géologique sur le Bas-Boulonnais' 1892, p. 13):—

Phorus bouchardi.	*Rhynchonella ferquensis.*
Natica spp.	*Streptorhynchus devonicus.*
Machrocheilus schlotheimi.	*Orthis striatula.*
Murchisonia bilineata.	*Leptæna dutertri.*
Loxonema hennahiana.	*Strophomena latissima.*
Straparollus.	*Chonetes armata.*
Turbo.	*Strophalosia productoides.*
Dentalium.	*Productus subaculeatus.*
Bellerophon tessellatus.	*Acervularia davidsoni.*
Aviculopecten neptuni.	*Cyathophyllum bouchardi.*
Limanomya grayiana.	*C. profundum.*
L. multicostata.	*Favosites dubia.*
Athyris concentrica.	*Thecostegites bouchardi.*
A. concentrica, var.	*Smithia boloniensis.*
Atrypa reticularis.	*Alveolites subæqualis.*
A. longispina.	*Chætetes goldfussi.*
Spirifer bouchardi.	*Metriophyllum.*
S. verneuili.	*Retepora antiqua.*

Fiennes Shales.—Immediately above the limestones, and grading into them, appear fine-grained greyish-chocolate shales. They are well seen at the Beaulieu brickworks and in Beaulieu Wood; elsewhere they may be traced by the colour of the soil and the tendency to form bogs and ponds. Fossils are rare; but the following are recorded by Rigaux:—

Leptæna latissima.	*Spirifer verneuili.*
Chonetes armata.	*Camarotœchia ferquensis.*

The thickness of these beds is 324 feet.

Famennian.

Fiennes Sandstone.—This is divisible into two parts: the lower is yellow or brown, finely-bedded, sometimes micaceous sandstone; the upper is pure white, with a green or grey tinge, finely bedded or apparently compact. The lower beds are seen in two quarries in Beaulieu Wood at Le Hure and at Ferques; the upper beds in a quarry in Beaulieu Wood, in two quarries at Le Hure, and opposite the crucifix on the high road near Le Hure. They are unfossiliferous; but *Bellerophon* is recorded by Rigaux, and some lamellibranchs by Godwin-Austen.[1] The exposures at Hydrequent, Sainte Godeleine, and Rougefort are of similar rocks, but the white variety is not seen, and the beds appear to be of much greater thickness than the Lower Fiennes Sandstone; they may, therefore, belong to a higher horizon than the Le Hure beds. *Cucullæa hardingi*, *C. trapezium*, and *C. amygdalina* have been recorded from Sainte Godeleine (Godwin-Austen, *loc. supra cit.*).

The Upper Famennian is absent, either owing to non-deposition, or to thrust-faulting; but it may occur under the Jurassic rocks near Sainte Godeleine.

The maximum thickness in the main area of these sandstones is 585 feet.

Tectonic Structure.

The lowest beds of the Devonian System which are exposed consist of a coarse conglomerate with rounded pebbles. Within half a mile Lower Palæozoic rocks have been detected in a boring, which are identified by the presence of a graptolite: D. Sharpe[2] was of opinion that the remains were those of plants, but his opinion has not been supported. These two facts point to the proximity of a Lower Palæozoic coast-line and the absence of the Lower Devonian rocks in this area, unless they are covered by overlapping of the higher beds. The Devonian rocks, therefore, rest unconformably on an old Lower Palæozoic surface, of which the coast-line ran close to the northern limit of this Palæozoic area. The Devonian beds rest conformably on each other, with the exception of a few thrust-planes of very small throw. They are, however, traversed by a large number of dip-faults, which give a more northerly trend to the general direction of the strata than their strike. These faults are confined to the Devonian rocks, and are therefore of pre-Jurassic age.

In the southern direction the Devonian strata end against the Carboniferous dolomite; but careful mapping shows an unconformity at the junction, the strikes of the Devonian and Carboniferous rocks being at various angles, differing by about 60°. In addition, the dip-faults end at the junction with the Carboniferous.

[1] Q. J. G. S. vol. ix (1853) p. 239.
[2] *Ibid.* p. 249.

It has been assumed that the Devonian rocks thin out on the western edge of the exposure; but there is no evidence of this. At La Malassise they are present in their normal thickness (except the Fiennes Sandstone); but at Eslinghen, in the Blacourt-stream valley, the Fiennes Sandstone, the Fiennes Shales, the Ferques Limestone have entirely disappeared, and the Carboniferous touches the Beaulieu Shales. This is evidently due to a thrust-fault, probably the one suspected at Eslinghen by J. Gosselet,[1] which also accounts for the occurrence of the Fiennes Sandstone (reported in a well at this farm) that would be out of its proper position. Traced eastwards, this thrust-fault fully explains the outcrops of the Carboniferous dolomite in relation to the Devonian beds; finally, running down the lateral valley at Le Hure, it can be seen in a new quarry, at the railway-crossing, as the junction between the two systems. Farther eastwards it may bend slightly to the south, or be shifted southwards by a dip-fault.

Corroborative evidence of the existence of this thrust-fault is afforded by the absence of the uppermost Devonian beds and the beds equivalent to the Yoredale Shales, etc. The thickness of the sandstones at Hydrequent and Sainte Godeleine, if not exaggerated by faulting, shows that a much greater thickness of sandstone was deposited towards the south. Borings made near Le Waast and at Menneville, Bournonville, and Wirwignes, farther south, revealed black shales (accompanied at Le Waast by red sandstones) which are referred to the Upper Devonian,[2] but belong to a different facies from those of this area, and may represent the missing beds.

This thrust-fault is parallel to the one which bounds the inverted Carboniferous beds, passing immediately south of Ferques, and also to others which occur farther south, and appears to be of the same age and due to the same thrust from the south, as that which is known as the Hercynian movement.

Minor thrust-faults may occur between the Devonian and the Silurian; but there is no direct evidence, except the reported occurrence of Devonian rocks at Guines, possibly in an outlier resting on the Silurian plateau (Brabant Tableland).

The beds form the northern half of the Namur Basin, the Lower Palæozoic (probably Upper Silurian) to the north representing the Brabant Tableland. The southern half of the basin is represented by the Carboniferous Limestone of the Vallée Heureuse and the Devonian of Hydrequent and Sainte Godeleine. The overthrusting here is so severe that the beds are inverted. Farther south still, the Condroz crest[3] has been identified by means of borings in the Liane Valley (Chantraine).

The Devonian rocks have remained practically unaltered; the shales are soft enough to be cut with a knife, and there is no trace of slaty cleavage.

[1] 'Étude sur le Terrain Carbonifère du Boulonnais' Mém. Soc. Sci. Agric. & Arts de Lille, ser. 3, vol. xi (1873) p. 7.

[2] J. Gosselet, Ann. Soc. Géol. du Nord, vol. xxvii (1898) p. 141.

[3] *Id. ibid.*

The Devonian period in this area appears to have opened with shore-deposits of conglomerate, which would overlap each other as the basin sank. In the next stage sandy deposits were laid down, with remains of plants. Even the limestones were formed in a shallow sea, in places being coral-reefs; while the typical black or grey colour is due to organic remains. The two series of dolomite were probably the result of periods in which conditions especially favoured reef-formation, though they do not appear to be coral-reefs, but formed from the accumulation of calcareous débris. The period is closed by deposition of fine-grained sands, indicating a shallower and less tranquil sea: in this last stage the amount of iron-oxide is decidedly less, as indicated by the lighter coloration, than in the earlier stages; this may be due to some comparatively sudden change in the area draining into the sea, either by alteration of the river-courses or of the currents.

The land continued to sink during Carboniferous times, but in the great Hercynian movement a mountainous mass of Carboniferous and Devonian strata was piled up. The thrust from the south which caused this movement was resisted by the Brabant Tableland, but the coast-line of the seas in which the Devonian and Carboniferous deposits had been laid down was slightly oblique to the direction of the thrust; the Devonian rocks, therefore, moved slightly on the Silurian beds, and relieved the stresses set up (except that of compression) by fracturing along the planes of the dip-faults, and moving in blocks progressively more to the north from east to west.

In the district between the Devonian exposures and the coast, borings have revealed similar beds at depths of 574 feet (Wissant) and 597 feet (Hervelinghen) below sea-level. There is, consequently, a difference in the level of the Devonian surface at La Capelle and Hervelinghen of 909 feet. Borings have also revealed the presence of Carboniferous rocks farther north at Strouanne, etc., and the Kent Coalfield lies still farther in that direction. Gosselet[1] suggested the presence of a great fault west of the Calais-Boulogne road, to explain the distribution of the beds as revealed by the borings; but there seems to be no other evidence of it.

The presence of a great thickness of Jurassic deposits indicates that the spot at which they were found was remote from the edge of the depression in which they were laid down. The Mesozoic coast-line must, therefore, have taken a decided northerly trend west of the Calais-Boulogne road. The basin in which the Jurassic deposits were laid down and the Devonian-Carboniferous basin correspond in a general manner; the old Silurian coast-line, therefore, also probably took a northerly trend at this point, and passed to the north of Strouanne and the Kent Coalfield. Consequently, at Hervelinghen pressure would be applied at a much greater distance from the supporting Silurian massif, and the resultant structure would differ from that of the exposed Devonian, becoming more complex with overfolding as well as faulting.

[1] Ann. Soc. Géol. du Nord, vol. xxvii (1898) pp. 143–44.

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Do. 'La Faille d'Hydrequent' *Ibid.* vol. xxxii (1903) p. 131.

Do. 'Considérations générales sur les Divisions & la Disposition du Terrain Dévonien dans le Nord de la France & en particulier dans le Boulonnais' Bull. Soc. Géol. France, ser. 3, vol. viii (1880) p. 491.

R. ZEILLER. 'Sur les Empreintes Végétales des Grès Dévoniens de Caffiers' *Ibid.* p. 501.

E. RIGAUX. 'Notice Géologique sur le Bas-Boulonnais' Mém. Soc. Acad. de Boulogne, vol. xiv (1889) 1892, p. 5.

Do. 'Le Dévonien de Ferques & ses Brachiopodes' Boulogne, 1908.

M. MOURLON. 'Considérations sur le Dévonien Supérieur (Famennien) de la Carrière du Bois de Beaulieu, &c.' Ann. Soc. Géol. Belg. vol. xxxi (1904) p. B 214.

E. MAILLIEUX. 'Étude comparative de la Répartition des Espèces Fossiles dans le Frasnien Inférieur, &c.' Bull. Soc. Belge de Géol. vol. xxiii (1909) Mém. p. 115.

EXPLANATION OF PLATE XIV.

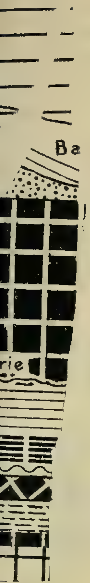
Geological map and section of the neighbourhood of Ferques, on the scale of 3·125 inches to the mile, or 1 : 20,275.

DISCUSSION.

Mr. L. D. STAMP congratulated the Author on the interest of the district in which he had worked, and emphasized its importance in a comparative study of British and Continental Devonian rocks. The existence of a thrust-fault between the main tract of the Devonian and the Carboniferous Limestone on the south elucidated many difficulties. In Haut Banc Quarry, about 1 kilometre away to the south, blocks of limestone with a typical Tournaisian fauna had recently been found in a thrust-plane, proving the existence of these beds in the district, although in the area described by the Author only a small thickness of dolomites occurred below the fossiliferous Viséan limestone. The new thrust-fault found by the Author showed that the absence of the Tournaisian and part of the Famennian was due to faulting. Dip-faults or 'tears' have been proved in the Carboniferous to the south by Olry,[2] but his maps showed them displacing the outcrop of the main thrust-planes. Was it not possible that the dip-faults in the Devonian continued into the Carboniferous, and were later than the main thrusts? The speaker did not think the evidence sufficient to

[1] A remarkable omission (especially as it contains a valuable map) is Gosselet's 'Étude sur le Terrain Carbonifère du Boulonnais' Mém. Soc. Sci. Agric. & Arts de Lille, ser. 3, vol. xi (1873) p. 7.

[2] Bull. Serv. Carte Géol. France, vol. xv, 1904.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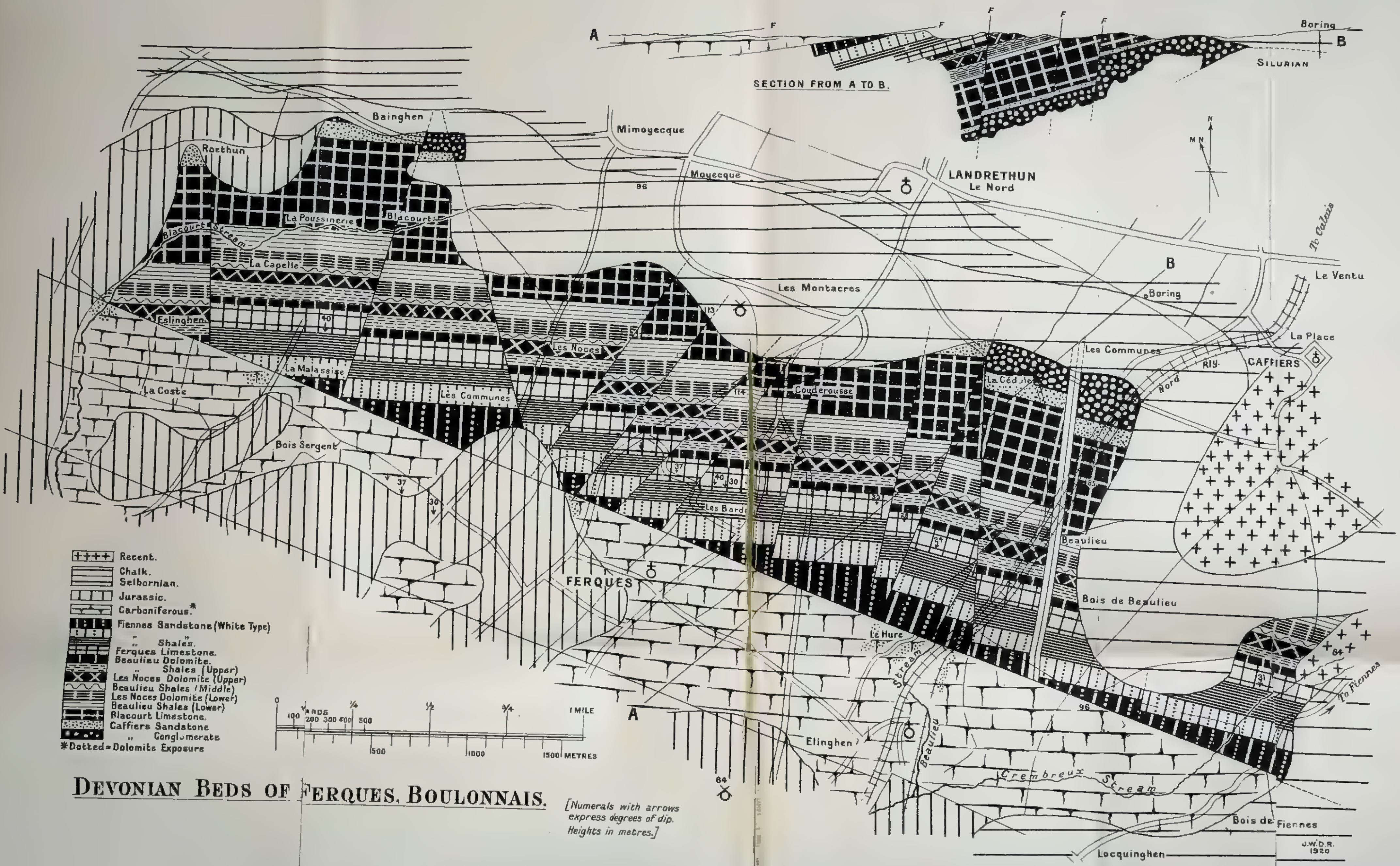


DEVONIAN BEDS OF FERQUES, BOULONNAIS.

[Numerals with arrows express degrees of dip. Heights in metres.]

warrant any conclusions on the trend of the Devonian coast-line, and thought that the more northerly occurrence of Devonian on the west was more simply explained by one or several dip-faults with a greater throw.

The Author mentioned the sporadic occurrence of the Les Noces Dolomites. Undoubted reefs were characteristic of the Frasnian in the Bassin de Dinant. Was it not possible that here was a case of small dolomitized reefs?

With regard to the plant-remains in the Grès de Caffiers, specimens collected by the speaker had been identified, as accurately as their preservation allowed, by Prof. Bertrand, of Lille, as *Hostinella* sp. (Halle) and the sporangial bodies, *Dawsonites arcuatus* Halle. At Matringhem these were associated with *Psilophyton princeps* (Dawson *pars*) Halle. It was important that such determinations should be as precise as possible, as a careful study of Devonian plant-fragments might prove them to possess stratigraphical importance.

The Author replied that there was undoubtedly a system of dip-faults in the Carboniferous; but, if they were once continuous with those in the Devonian rocks, as was probable, they had been displaced by the thrust-fault. It was possible that there was a later set of faults having the same general direction. The appearance of detached masses exhibited by the Les Noces Dolomites was assignable to the shifting of the outcrop, otherwise they appeared to be continuous beds: the hummocks seemed to be caused by unequal weathering due to the varying character of the rock, in places compact, in others loose and cavernous; corals were rare in these beds. There was no evidence of considerable dip-faults on the west to account for the facts revealed by borings, but the sea-floor was undoubtedly lower on the west during the Mesozoic Era; it seemed, therefore, to be an equally probable explanation that the coast-line receded northwards.

7. *A* NATURAL 'EOLITH' FACTORY *beneath the* THANET SAND.

By SAMUEL HAZZLEDINE WARREN, F.G.S. (Read May 5th, 1920.)

[PLATE XV.]

EXPERIMENT has shown that the mechanical movement of one flint grinding against another under pressure will produce edge-chipping similar in every respect to that which is seen upon the Eoliths.

Direct evidences that such processes have actually been in operation in Nature have been brought forward by M. l'Abbé H. Breuil[1] and Mr. F. N. Haward,[2] as also by the present writer[3]; but more comprehensive knowledge of the work of Nature is urgently needed.

One must never forget that static energy in equilibrium is ineffective: there must be some disturbance of equilibrium for any chipping force to be set in action. That is to say, there must be at least vibration, but the greater the differential movements, and as a consequence the more the stones grind over each other, the more favourable the conditions become for the production of edge-chipping.

Certain types of superficial drift fulfil these conditions, through the prolonged operations of soil-creep, better than they can be fulfilled in more deeply seated situations. But the Eoliths that are found in them, which some investigators believe to be results of these mechanical movements, can always be claimed by others as human implements.

The conditions at the base of the Tertiary System do not always fulfil what is needed. The section at Harefield can be taken as a good illustration: here is evidence of immense pressure, without any appreciable amount of differential movement. In consequence we find that the fractures are promiscuous, and strike through the heart of the flints in any direction, and there is a general absence of that type of edge-chipping which is produced when the flints grind over each other.

In the Bullhead Bed, exposed in the big chalk-pit to the west of the Stifford road at Grays in Essex, the conditions are much more favourable. The great development of slickensides gives sufficient testimony to the differential movements which have taken place.

The accompanying diagrammatic section will make the relation of the deposits clear. At the top is the contorted Trail, usually

[1] 'Sur la Présence d'Éolithes à la Base de l'Éocène Parisien' L'Anthropologie, vol. xxi (1910) p. 382.

[2] Proc. Prehist. Soc. E. Anglia, vol. i (1912) p. 185; *ibid.* (1913) p. 347; and vol. iii (1919) p. 118.

[3] Journ. R. Anthrop. Inst. vol. xliv (1914) p. 431.

measuring up to about 9 feet in thickness. Near the middle of the section is a River-Drift channel cutting through the Thanet Sand, the relation of this to the Trail being a little obscure. Below the Thanet Sand is the Bullhead flint-bed resting upon a horizontal but corroded surface of the Chalk.

Where the specimens described in this paper were collected there was nothing in the nature of piping, the corroded irregularities of the Chalk surface beneath the Tertiaries being on quite a small scale.

The Bullhead flint-bed, left from the solution of the Chalk, is about 9 inches thick, and there is a thin layer of banded residual material at the base. The upper flints of this bed are not only green-coated, but deeply altered through their substance, and much corroded on their surfaces. The lower flints are much fresher in condition, while those next the Chalk have not yet become green-coated, and after removal they could not be recognized as Bullhead flints. Many of them still remain partly embedded in the parent rock. The outstanding feature at Harefield is that the sub-Tertiary Chalk surface, with its tubes of boring organisms, still remains practically unaltered since it formed the floor of the Eocene Sea. The outstanding feature at Grays is the extensive solution of

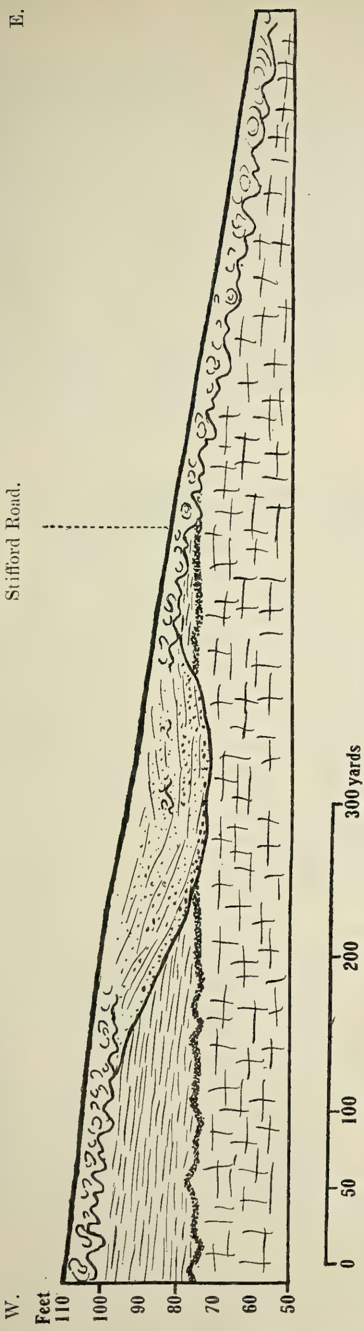
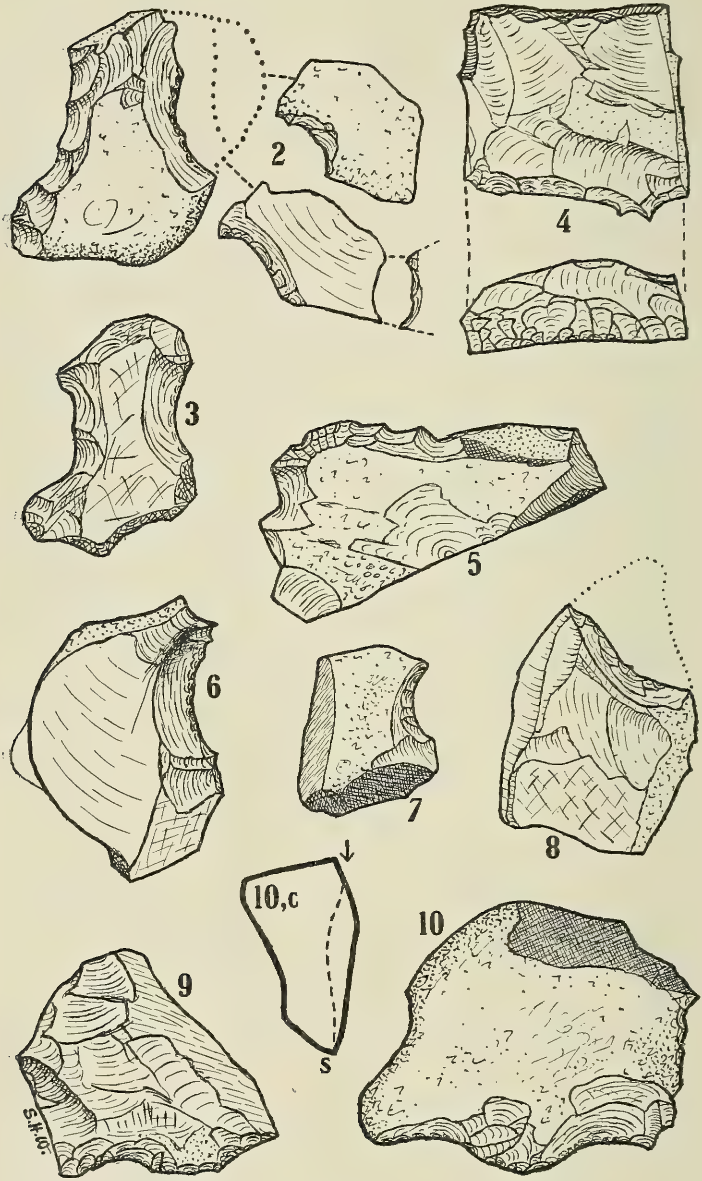


Fig. 1.—*Diagrammatic section near the northern end of the Grays Chalk-Quarry Company's pit.*

Figs. 2–10.—*Kentish forms of Eolithic chipping.*



S. H. W. del.

[Scale: $\frac{1}{2}$ (10 *c*, $\frac{3}{4} \times \frac{1}{2}$.)]

the Chalk surface which has taken place in comparatively recent geological times.

To dig the flints out of this deposit, to note the pressure-points of one stone against another, and the resultant effects, is a liberal education in the study of natural chipping. In many instances the flakes which fit the facets upon the pseudo-implements still remain in their original positions, and may be recovered in place.

(A) Pressure-Cones.

These are produced when a force of sufficient magnitude acts centrally (and not on the edge) of a flint. This is an important point in the general understanding of natural flint-chipping, but it can never be mistaken for human workmanship. Moreover, it has, I think, been sufficiently dealt with in previous publications.

(B) Kentish, or Plateau, Forms of 'Eolith.'

(1) Pl. XV.—Photograph of a flint with a small 'Eolithic' notch squeezed out of its edge; it is shown in place in the residual banded layer of the Bullhead Bed, with the slickensided under surface next the Chalk. The length of the notch=17·5 mm.

(2) P. 240.—Flint with a large open notch squeezed out of either side. Dimensions, 67 × 53 × 29 mm. The average chipping-angle, neglecting the extremes, is about 80°. (This will be given in the same manner in each case, unless otherwise stated.) Each of the two larger chips which were recovered in place from the right-hand side had an 'Eolithic' notch squeezed out of its edge by cross-pressure.

(3) Kentish Eolith, collected by Mr. B. Harrison, of the same essential form as (2). This illustrates the fact that many Kentish Eoliths may be paired with Bullhead chippings. 66 × 44 × 25 mm., 80°; the extremes being from 65° to 105°.

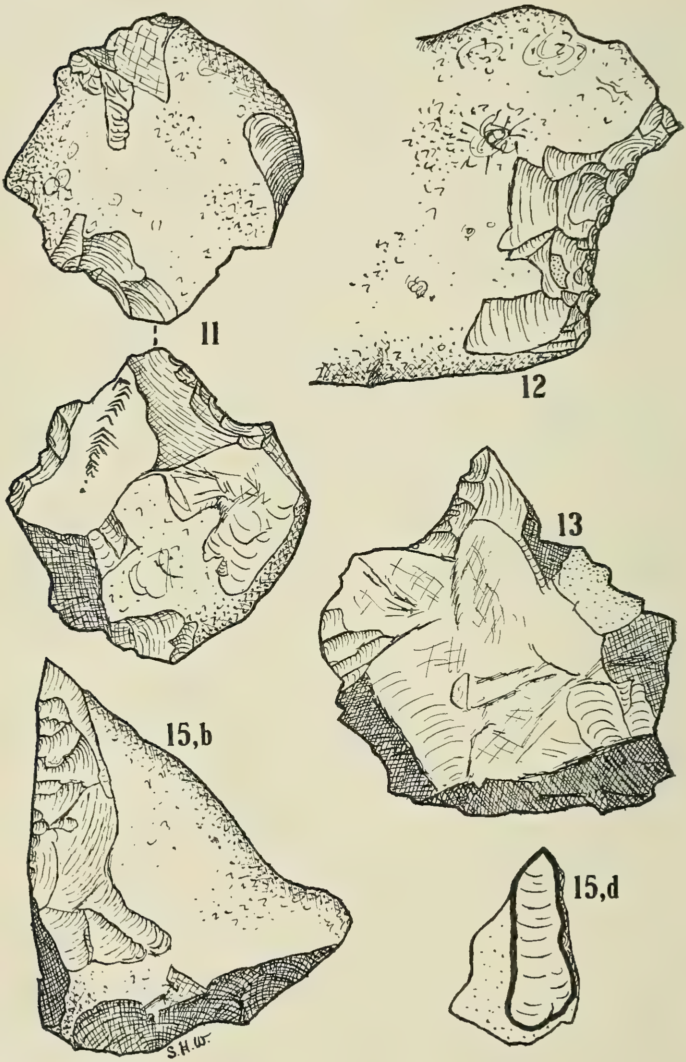
(4) Rectangular 'scraper,' with separate view of the chipped edge. A particularly fine example of regular flaking, superior to the average Eolith. 58 × 59 × 23 mm.

(5) 'Scraper' with engrailed edge. A characteristic Kentish form. 90 × 45 × 30 mm., 73°.

(6) Oblique view of a single notch, found in the top of the Chalk, a piece of which is still adherent to the back edge. 78 × 55 × 27 mm. The chipping-angle swings from about 70°, through 100°, up to 130° on the crushed and blunted edge, the same features being frequently seen upon the Kentish flints.

(7) Small single notch; this represents the ideal type of the Kentish group. 42 × 33 × 16 mm., 80°.

Figs. 11–15.—*Kentish and sub-Crag forms of chipping.*



S. H. W. del.

[Scale : $\frac{1}{2}$ (15 *d*, $\frac{1}{2} \times \frac{1}{2}$.)]

(8) Oblique notch, leading on towards a small rostro-carinate form. More than a dozen separate chips were recovered in place, which build the specimen up to the dotted outline. $60 \times 49 \times 22$ mm., 87°.

(9) Double notch, made from a flake from which the bulb has been entirely removed by subsequent 'facetting' of the butt-end. $65 \times 55 \times 29$ mm., 83°.

(10) A better example of the same form, made from an outer flake with bulb. As a possible useful implement this specimen is greatly superior to the majority of the Kentish eoliths of corresponding form. $73 \times 80 \times 39$ mm., 80°. (10 *c*) Longitudinal section (scale $\frac{3}{4} \times \frac{1}{2}$) with the bulb at the arrow and the scraping edge at *s*. The flake shows normal characteristics of mechanical pressure; the normal curvature produced by a smart human blow is indicated by the dotted line.

(11) This specimen illustrates the making of a drill-like point by reversed notches; further search would doubtless be rewarded by the discovery of better examples. A polished mark, associated with a series of V-shaped incipient fractures, indicates the passage of an intermittent jolting force, which produced one of the notches where it passed off the edge. Among these Bullhead flints such marks are usually lines of high polish, and not scratches. Upon exposure to atmospheric influences, the crushed flint would weather out and leave a slight groove. Similar association of scratches with the chipped edges may be traced upon the Kentish flints. $83 \times 79 \times 41$ mm., 85°.

(12) This is the finest example in the series of a broad 'Eolithic' notch; most of the flakes were recovered. It happens unfortunately to be on a heavy and clumsy nodule, measuring $179 \times 111 \times 71$ mm., the length of the notch itself being 63·5 mm. The chipping angle swings round from about 60° up to 110° or 115° on the crushed edge, in the manner so characteristic of the Kentish flints.

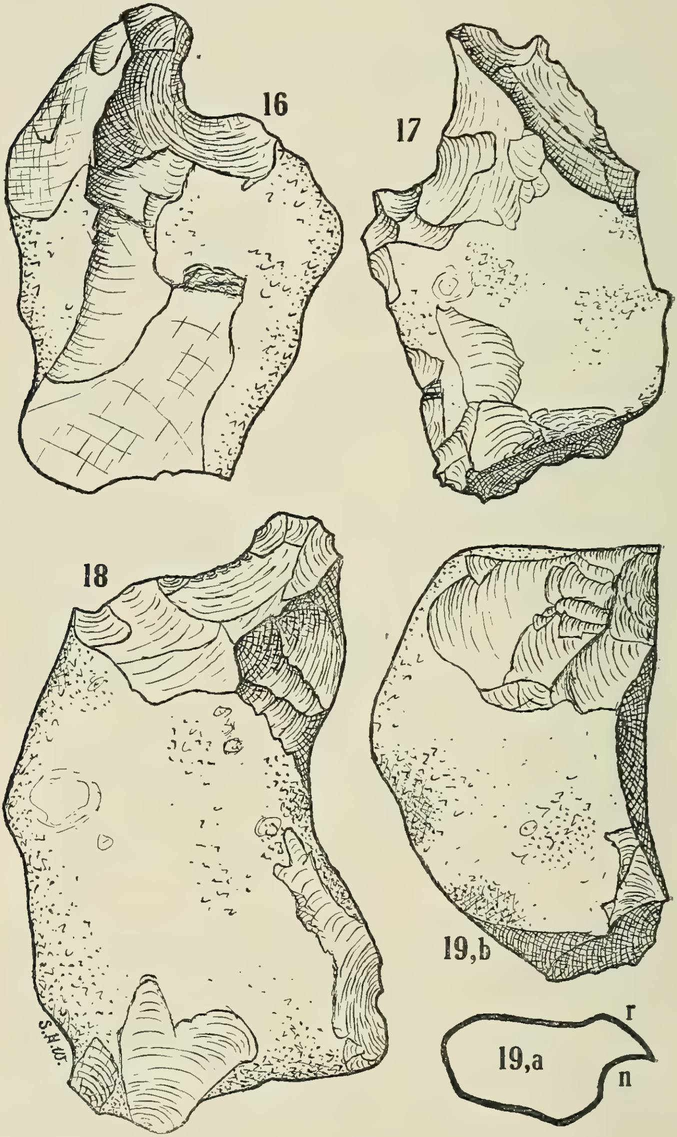
(13) Acutely-pointed form, with the notch on the left of the point. $101 \times 94 \times 42$ mm., 77°.

(C) The Rostro-Carinate Group.[1]

Although larger, the flints of this series show the same essential Eolithic characters as the Plateau flints of Kent. That is to say, they present high-angle edge-chipping, mainly in one direction,

[1] There are differences of opinion on the use of the term 'rostro-carinate.' As I see the matter, there is a well-defined group of flaked flints, equally characteristic of both the sub-Crag and the Bullhead series, which is (in fact) of rostro-carinate form, whether all of them be called 'rostro-carinates' or not. A more restricted delimitation in the application of the term will reduce the proportion of 'rostro-carinates' in both series; but it will not alter the similarity of the one series to the other.

Figs. 16–19.—*Carinate sub-Crag forms of chipping.*



S. H. W. del.

[Scale: $\frac{1}{2}$ (19 *a*, $\frac{1}{2} \times \frac{1}{2}$).]

with the notch ['encoche'] forming a prominent feature in the forms produced.

(14) Pl. XV.—Photograph of an unfinished rostro-carinate in the making, shown from the under surface, with the series of flakes removed. $107 \times 67 \times 48$ mm., 80°.

(15 *b*) P. 242.—Side view of carinate form, showing the details of the flaking. (15 *d*) Basal view, showing the 'ventral plane,' made by one long clean flake-scar, from which the flaking along the edge was subsequently removed. $112 \times 57 \times 90$ mm., 90°.

(16) P. 244.—Claw-like form; the major flake from the notch was found in place, while the basal plane was formed by a fracture of earlier date. $142 \times 91 \times 71$ mm., 85°.

(17) Another good example of the same form, the basal plane being formed of the natural cortex of the nodule. The apparent intelligence in the flaking of the butt-end for the accommodation of the hand-grip is particularly striking. $127 \times 87 \times 60$ mm., 86°.

(18) This is also a notable rostro-carinate, with double curvature, and again some flaking at the butt-end for the apparent accommodation of the hand-grip. $169 \times 91 \times 53$ mm., 85°.

(19*b*) Side view of a flint which closely resembles one of the sub-Crag type-specimens preserved in the British Museum. (19 *a*) Outline, seen from above (scale $\frac{1}{2} \times \frac{1}{2}$), *n* being the notch shown in the lateral view. There is no flaking in this case round the outer curve *r*, but notable shaping at the butt-end for the apparent accommodation of the hand-grip. The basal plane is remarkably well 'prepared' by clean fracturing. The largest flake with very good pressure-bulb was recovered, but the smaller chips were too severely crushed for useful preservation. $114 \times 59 \times 74$ mm., 95°.

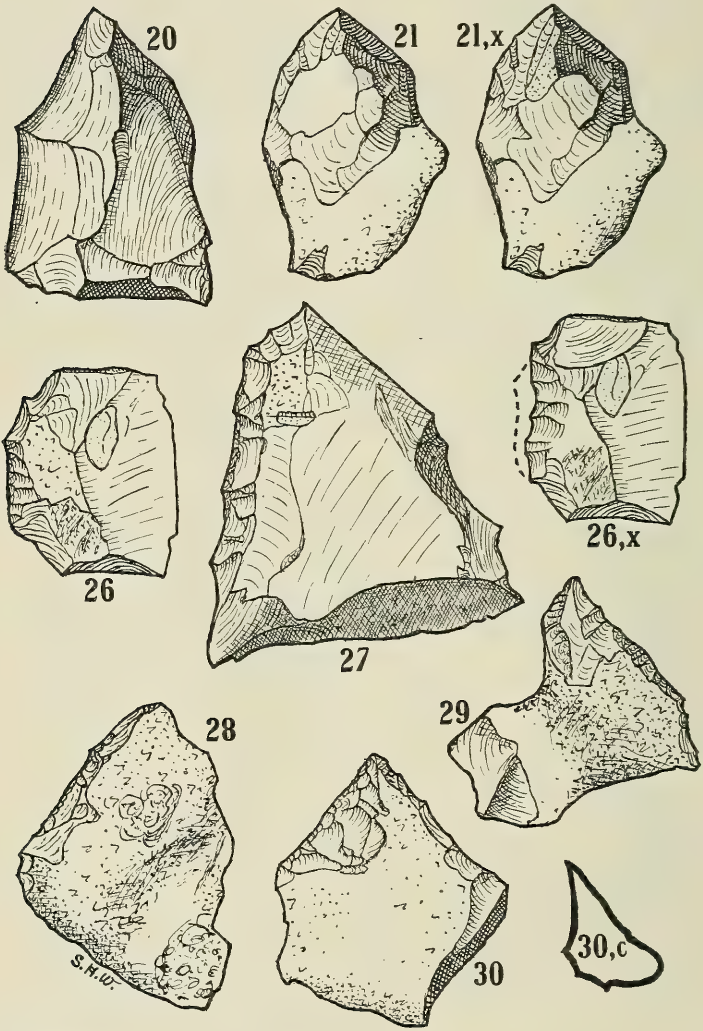
(20) P. 246.—Straight carinate form, of triangular section, resembling the inverted prow of a boat. $76 \times 48 \times 46$ mm.

(21) This belongs to the same group as 20, but it more nearly resembles the celebrated sub-Crag 'test-specimen' on a slightly smaller scale. The basal plane is formed of a hinge-fracture. The last flake removed, which truncates slightly more patinated facets, was recovered; but the earlier flakes appeared to have been carried away by the movements of the soil, as careful search immediately around the specimen failed to disclose them. The second drawing, 21 *x*, shows the specimen with this last flake replaced. $72 \times 48 \times 38$ mm.

(D) The Flakes.

The best selected flakes from this bed are by far the finest examples of mechanical, or non-human, flaking that I have ever seen: and, if they were mingled with flakes from a prehistoric working-floor, they could never be separated again, unless it were

Figs. 20–30.—*Sub-Crag forms (20, 21), and exceptional resemblances to human flaking.*



S. H. W. del.

[Scale: $\frac{1}{2}$ (30 *c*, $\frac{1}{2} \times \frac{1}{2}$).]

by their mineral condition. But this need not occasion undue misgiving in the separation of the work of Nature from the work of Man: such exceptional specimens are condemned by their associates.

We must distinguish a geological deposit of chipped flints from the débris of a prehistoric chipping-floor, by taking fairly representative groups. One can easily become unconsciously deceived by over-selection.

The characters of human and non-human flaking can only be properly appreciated by first-hand experiment; but it is hoped that a comparison of 10 *c* (p. 240), and 22, 23, & 24 (Pl. XV) will be of material assistance.

(22) Pl. XV.—Photograph of two conjoined flakes showing normal pressure-characters; that is to say, the bulb consists of a broad, but ill-defined and only slightly-elevated, swelling. Dimensions of the two together $=80\times93\times22$ mm.

(23) Pl. XV.—Photograph of four conjoined flakes, also showing normal pressure-characters, but 'struck' from an apparently well-prepared platform. $53\times50\times12$ mm., 88°.

(24) Pl. XV.—Photograph of a large flake with conical bulb which is practically indistinguishable from a normal 'human' example: that is to say, the bulb has more the form of a sharply-defined cone,[1] it is more elevated, and also cross-cut by the éraillure which was formerly supposed to be the exclusive character of the human blow. This specimen is of non-pressure character, and must represent some sudden jolt or jerk in the soil-movements. $118\times136\times23$ mm., 80°.

(E) Exceptional Forms.

(25) Pl. XV.—Adze-like form, with good flaking at the end. This specimen had been pressed into the Chalk, and the photograph shows the slickensiding on the Chalk which still firmly adheres to the flint in the hollow to the left of where the numeral 25 is placed. All the flakes were recovered. $97\times60\times38$ mm., 70°.

(26) P. 246.—Small pseudo-râcloir, made from a good flake with bulb and éraillure. As in other instances in the Bullhead series, there are numerous further secondary flakes in process of being removed from the trimmed edge, but the fractures are not yet sufficiently completed to cause their separation. The second drawing, 26 *x*, shows the approximate appearance which the specimen would assume were the present incipient flakings completed. $56\times45\times29$ mm., 80°.

(27) This is a very fine 'side-scraper.' One has to search far in order to find an Eolith that is its equal. $83\times98\times31$ mm., 85°.

[1] These characters refer to the effects of a simple, direct, human blow. There are more advanced techniques of human flaking which produce entirely different results.

(28) Right-handed oblique 'scraper.' 73 × 63 × 47 mm., 73°.

(29) Left-handed oblique 'scraper.' This right- and left-handed pair, 28 & 29, are astonishingly alike in form, and would constitute a most potent argument for intelligence in design. 74 × 60 × 56 mm., 85°.

(30) This, a good example of a trimmed-flake point, is the most remarkable specimen of the group. If considered by itself, upon its own apparent merits, and away from its associates and the circumstances of its discovery, its Mousterian affinities could scarcely be questioned. But, like all the other specimens illustrated, I dug it out of the Bullhead Bed myself in circumstances which preclude the possibility of mistake. When examined critically in comparison with its associates, it is seen to belong to the same group. Dimensions = 77 × 66 × 39 mm. On the left the average chipping angle is about 58°, which is very exceptional for mechanical pressure, but on the right it is about 85°. (30 *c*) Longitudinal section, scale $\frac{1}{2} \times \frac{1}{2}$.

The last specimen emphasizes the moral that, in order to arrive at a sound judgment upon the origin of a chipped flint, it is necessary to make a critical comparison of its immediate associates, to take into consideration the circumstances of its discovery, and also the evidence of the geological forces to which it has been exposed. A geological deposit of chipped flints may supply many individual specimens which are practically indistinguishable from the work of Man.

No figures can adequately represent the true characters of the specimens, but, through the kindness of the authorities, a selection of those illustrated here may be seen in the British Museum (Natural History), South Kensington.

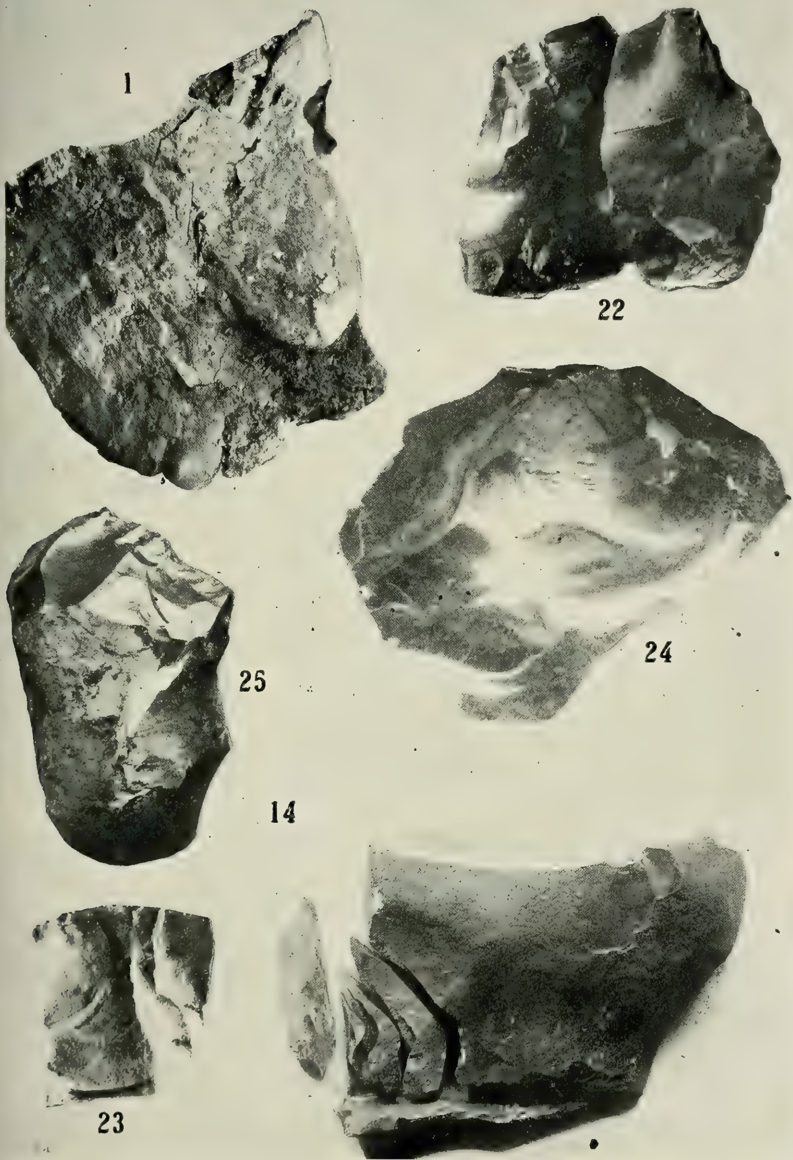
In conclusion, it only remains for me to thank the management of the Grays Chalk-Quarry Company for the facilities which they have afforded to me for carrying out this investigation in their pit.

Postscript.

[Since the reading of the paper, I have had an opportunity of showing the whole of the Grays series to M. l'Abbé H. Breuil, and he remarked on their general similarity to the chippings discovered by himself in a corresponding geological position at Belle-Assise. The Grays evidence is, however, more comprehensive, particularly with regard to the larger (rostro-carinate) forms, which he tells me are absent from the French site, the flints being of smaller size. —*S. H. W., July, 1920.*]

EXPLANATION OF PLATE XV.

Natural flint-flakings, produced by sub-soil pressure, found in place in the Bullhead Bed at Grays (Essex). Approximate scale: a half to a third of the natural size. For detailed description and exact dimensions, see the text.



S. H. W. photo.

FLINT FLAKINGS FROM THE BULLHEAD BED AT GRAYS.

[Scale: a half to a third of the natural size.]

Discussion.

Mr. H. Dewey, after congratulating the Author on the work that he had completed, remarked that, if the Author's conclusions were correct, they cut deeply at the roots of much modern speculation as to the antiquity of Man. If natural agencies are operative in the production of form and fracture of flints hitherto supposed to be characteristic of human work, it behoves prehistorians to review their theories, and to establish such criteria of human workmanship as are irrefutable.

The speaker asked for evidence that the Author's specimens had occurred undisturbed in the Bullhead Bed, and remarked on a difficulty which, he felt, needed explanation. It is a fact that sub-Tertiary solution is a phenomenon of widespread occurrence and, as shown by the Author, one capable of producing flints resembling Eoliths and rostro-carinate forms, yet over the part of the Chalk plateau between the valley of the Mole and that of the Medway, where true Eoliths find their home, the speaker had never found a form referable to the rostro-carinate type, nor had he ever seen an Eolith that had been made from a green-coated flint. The fact that the rostro-carinates of Suffolk had hitherto been found lying only upon Tertiary beds, and not upon the Chalk beneath, also militated against the origin postulated by the Author.

The speaker further remarked upon the ambiguous position of implements of Le Moustier type; recent researches have led to the claim that they belong to the Preglacial, the Palæolithic, and the Neolithic periods, and now natural agencies are claimed as capable of producing them. Their value, therefore, as 'zonal fossils', to the stratigrapher was *nil*.

Mr. Reginald Smith pleaded for a stricter definition of 'Eolith,' and would prefer to see the term applied only to the ochreous specimens with steep edge-chipping found principally on the North Downs, and so named in 1892. In a paper on a parallel deposit at Belle-Assise (Oise), published in 'L'Anthropologie' for 1910, the Abbé Breuil had spoken of Eolithic work on crushed flints from a horizon corresponding to the Bullhead Bed; but the specimens figured were not of the North Downs type. It was unfair to judge of Eoliths by the half-dozen exhibited; but even those seemed to differ from the Eocene specimens. The most convincing Eolith that he had seen was in the Stopes Collection, in the National Museum of Wales, and poor specimens only confused the issue. The large flake with prominent bulb was certainly suggestive of Le Moustier, but Nature might easily produce one good flake in a million. There were certain features due to percussion that helped to distinguish human work from the results of natural pressure; and careful comparison with a dozen specimens from Le Moustier would show that the scraping edges on exhibition were quite distinct from those of the Cave period. Doubtless continual reminders of Nature's capabilities were necessary, but the result was in some cases to destroy all confidence,

and discourage research in the early deposits where the most primitive implements were awaiting recognition.

Sir Henry Howorth thought that the facts which the Author had brought before the Society were important and illuminating. They went far to support the view that the case for the existence of Man in Tertiary times in our latitudes is not attested by satisfactory inductive evidence, but is based on untenable premises.

The case for the existence of Tertiary Man is so weak, when brought face to face with both *à priori* and deductive arguments, that the burden of proof should be laid on the champions of the new views. The speaker considered that the case as yet presented rests at the best on a few doubtful and ambiguous facts, and ignores a great mass of most potent evidence on the other side. The Author had effectively demonstrated that the so-called 'Eoliths' were not Eoliths at all, since that name was already appropriated for French stones entirely different from the English examples. Those who hold that the wrongly-called English 'Eoliths' were not of human origin or the result of design, base their contention first on the fact that the vast majority of them have no assignable purpose, being, so far as can be seen, of no use to human beings; while the relatively few to which some purpose could perhaps be assigned are either accidental freaks or else aberrant Palæolithic forms. To contend that the biting of the edges of flakes and angular fragments into a series of notches can only be assigned to human initiative, is simply an attempt to carry the position by the use of a negative instead of a positive argument.

In France and England most effective experiments have shown that similar phenomena can be produced by machinery adapted to breaking hard stones, and the only question that remained to be tested was whether Nature was not capable of producing like effects. The reply that the results in the latter case are not precisely like those specimens which are assigned to human agency is a delusive argument, as no two worked flints are exactly alike. What is important, however, is the fact that such phenomena as the flaking of flints and occasional bulbs and also edge-knapping are produced by causes entirely apart from direct human effort. The likeness between the flaking produced by Nature and that produced by human agencies is sufficient to shift any burden of direct proof upon those who maintain the human origin of the stones; and this must not be done by a careful selection of picked specimens, but by a survey of the whole group. The Author had produced an unassailable instance of an undisturbed bed, underlying Tertiary strata, which contains a considerable series of most instructive specimens gathered together in a small space. In this bed specimens presenting every feature that has been quoted as a criterion of English 'Eoliths' have been obtained. Not only had the Author found the actual products of Nature's handiwork, but he had also shown effectually how the knapping had been produced.

Mr. H. Bury thought it unfortunate that such a discussion should have been raised without a fair representation of both sides of the case among the exhibits. The Author and Mr. Haward had brought forward the best specimens that they could find in support of their case; but for comparison they only produced some half-dozen very inferior Kentish Eoliths, and no sub-Crag implements at all. It was a mistake to suppose that believers in Pliocene Man had ignored these pressure-flaked flints from the Eocene beds; on the contrary, the differences in detail which they observed between the two categories formed an essential factor in their argument.

Mr. Walter Johnson, while admitting that the undoubtedly natural specimens from Grays disposed of the claims of a vast number of the Plateau flints, urged that the modes of origin were not alike. The Grays specimens had presumably been formed by slight differential movements and accompanying pressure, but in the case of the Kentish flints there had been much transportation, with rolling and concussion. Yet these Kentish flints still exhibited characteristic outlines and chipping. Assuming that they had ever been in the condition of the Grays flints, were we to suppose that, after having lost their characteristics by abrasion, as would be the case, they would have the Eolithic form and markings produced afresh? That Nature formed 'Eoliths' was evident; that Man also fashioned crude implements was equally plain from observation. If, from a large suite of Plateau flints, a fair proportion of Eoliths could be selected, which, by common consent, showed artificial agency, then the Eoliths must stand, whether called 'pre-Palæoliths,' or by any other name.

Mr. A. S. Kennard congratulated the Author on an important discovery, and considered that the paper strongly supported the claim for the human origin of the Kentish Eoliths. He agreed with the Author that it was unfair to decide from a few examples, and that the proper test was the whole group. Judged by this standard, neither of the series shown resembled the Kentish Eoliths, since the more numerous and characteristic specimens were quite unknown on the Plateau.

Mr. A. L. Leach agreed with the Author in thinking that the peculiarly notched and chipped edges produced on these sub-Eocene flints by unquestionable natural pressures were indistinguishable from the notched and chipped edges of the flints commonly termed 'Eoliths.' Moreover, certain features: for instance, strongly-marked bulb-scars or negative bulbs, which, when seen on selected specimens from the sub-Crag detritus-bed of East Anglia, appeared very suggestive of human work, were also present on these pressure-chipped flints. He was, therefore, of opinion that the Author's specimens, obtained from a definite sub-Eocene horizon where none but purely natural forces could have acted, threw much light on the probable mode of origin of 'Eoliths' and of other peculiarly chipped flints which were claimed to be products of pre-Palæolithic human handiwork.

Mr. J. F. N. Green felt that he must protest against a statistical error. The demand that provably natural objects equal to the best Eoliths, etc., should be produced was unreasonable, since the selectors of the latter had all the chipped flints of England to work on, while flints absolutely proved to be naturally flaked were few. Those who held Eoliths to be artefacts had a field a million times larger than that open to the holders of the opposite view, and should obviously obtain specimens more closely resembling human work. Nevertheless, their results were so small that Mr. Reginald Smith, who had previously referred the Society to the British Museum, now went to Cardiff. A case which had to rely on a specimen, hyperselected from an almost infinite range, was in a bad way.

Mr. F. N. Haward exhibited, in support of the Author's arguments, a small series of 'chipped flints' of various forms—bulbous flakes with and without edge-chipping, pieces of flat flint with 'one-edge' chipping (on one side only), and several 'rostro-carinate implement' forms from the Basement Bed (Zone C) at Eaton Pit, Norwich. He also exhibited a split unrolled Chalk-flint, found in three separated pieces (one above the other) in the gravel of a pipe in Eaton Pit. One piece showed a sharp split edge, well chipped along one side only, in a manner exactly similar to specimens in the Basement Bed (Zone C) above.

These specimens, the speaker considered, furnished important evidence, as they are not the result of searching over a great amount of material or over a large area, nor the result of 'selection.' Practically every flint in the Zone is more or less chipped, some far better than others.

The chipping on these specimens is of the same order as, and often exactly similar to, that of the so-called 'implements of the sub-Crag', and of many of the 'Eoliths' of the Kent Plateau.

In the first instance, the chipping on these Norfolk specimens was probably due (as in the case of the Author's specimens) to movement in the Basement Bed caused by dissolution of the Chalk below, and further, in the case of the Eaton specimens, to transportation as the gravel shifted one way or the other since its deposition. During this subsequent movement, the sharp edges would be further chipped, crushed, and abraded.

The speaker felt confident that the Author had found evidence which bears directly on the probable origin of the so-called implements of the 'sub-Crag' and the 'Basement Bed' of East Anglia and possibly some of the 'Eoliths' of Kent. In conclusion, he paid a personal tribute to the careful and thorough investigation of the fracture of flint carried on by the Author for very many years.

The Author thanked his supporters in the discussion, and, in answer to criticisms, said that he considered the Mousterian affinities to have been exaggerated by several of the speakers. The series exhibited was of purely Eolithic character, but there were a few specimens which resembled Mousterian work to an astonishing degree. In opposition to the remarks of Mr. Reginald Smith,

such specimens proved that it was unsound to select one exceptional example from an associated group: it was the ninety-and-nine which gave the scientific evidence for the origin of the one.

In reply to Mr. Dewey, he stated that the specimens had all been dug out of the deposit by himself. He certainly agreed that the Kentish Eoliths were not the same as Bullhead chipping. Mr. Green had effectively replied to the point raised by Mr. Bury. The possible work of Nature was, at present, very inadequately known. At the same time, the Bullhead rostro-carinates, although obtained from only a few square yards of the deposit, were good examples of their class. and the Author did not fear comparison of them by any unprejudiced person with the type series preserved in the British Museum.

In answer to Mr. Johnson, the Author said that the ultimate obliteration of flaking must surely depend upon the amount of the rolling, and not upon the origin of the flaking.

Mr. Kennard had not made allowance for differences in size. The Bullhead flakings represented the operation of a force which was greatly in excess of that necessary to effect Eolithic edge-chipping. The Eoliths from the comparatively superficial drifts represented the operation of the minimum of force. The two groups presented differences, but the greater [Bullhead] group included representatives of the less, and therefore discredited both equally.

The Kentish Eoliths placed on the table for comparison had been condemned by several speakers as unsatisfactory examples. These specimens all had the guarantee of Mr. B. Harrison or Mr. Kennard, and these authorities would be the last to mislead an avowed sceptic with examples which, in their opinion, would not adequately support their own cause.

8. *The* LOWER PALÆOZOIC ROCKS *of the* ARTHOG–DOLGELLEY DISTRICT (MERIONETHSHIRE). By Prof. ARTHUR HUBERT COX, D.Sc., Ph.D., F.G.S., and ALFRED KINGSLEY WELLS, B.Sc., F.G.S. (Read March 10th, 1920.)

[PLATES XVI–XX.]

CONTENTS.

I. INTRODUCTION.

THE district to be considered in this paper is situate on the southern flank of the Harlech Dome, and is underlain by strata of Upper Cambrian and Lower Ordovician age. The area is bounded on its northern side by the Mawddach Estuary, which separates it from the Harlech–Barmouth area of Lower Cambrian rocks. On its southern side the whole district is overlooked by the great escarpment of Cader Idris, from which, however, it is separated by a long straight fault-valley—the Llyn Gwernan Valley. The western boundary is formed by the valley of the Afon Arthog, while the eastern boundary lies near the town of Dolgelley. The area thus defined is about 8 miles long by 2 miles broad. The ground is represented on the Ordnance Survey maps, 1-inch (large-sheet series) 59 (Barmouth), and on the 6-inch quarter-sheets Merioneth 36 N.E., S.E., 37 N.W., with portions of sheets 33 S.W. and 37 N.E., S.W., and on the Geological Survey Map, Sheet 59 N.E. 1-inch (Old Series).

(a) Physical Features of the Area.

The ground between the two boundary-valleys, the Mawddach Estuary and the Llyn Gwernan Valley, is occupied by a hill-range, or rather by a series of ranges, made by the scarps of the various harder beds, and having a general west-south-westerly trend. The hills average 900 to 1000 feet in height, attaining their greatest elevation on Bryn Brith (1259 feet). They fall into two main groups, which are separated one from the other by a broad upland

hollow situate on the outcrop of a big granophyre-sill. On account of the prevailing high dip (about 40°), dip-slopes are frequently almost as steep as scarp-slopes. The regularity of the various scarps is considerably modified by the presence of numerous intrusive masses, by jointing and faulting, and also by the effects of rejuvenation of the drainage-system. Accordingly, the features appear very diversified and difficult to explain, until the geological structure has been worked out in detail.

The entire range is cut through by the deep gorge-like valley of the Afon Gwynant, and by the broader and shallower valley of the Afon Arthog, and the main drainage is accomplished by these two streams, especially by the former of the two. This stream has intersected the Gwernan Fault-valley in such a way that it now receives tributaries from both halves of that valley. It also receives numerous minor tributaries that flow as subsequent streams along small hollows on the outcrops of softer beds. The rejuvenation which is so marked in the main stream has not greatly affected the smaller tributaries, and as a consequence their valleys tend to hang above the main valley. Rejuvenation has not proceeded so far up the Afon Arthog, and therefore only the lower course of this stream runs through a gorge.

The hill-slopes facing the estuary and the lower slopes of the Gwynant and Arthog valleys are (or were) densely wooded. Elsewhere much of the ground is extremely rough and craggy, and remains entirely uncultivated. The more open ground is mainly used as a grazing ground for sheep and cattle, only very small patches above the wooded level in the Gwynant and Arthog valleys being devoted to tillage. The scenery is accordingly varied, the estuary of the Mawddach and the district around Dolgelley being numbered among the most picturesque areas of North Wales, and exposures are everywhere so numerous that there is no need to indicate individual exposures on the map.

(*b*) History of Previous Research.

The geology of this strip of country is intimately related to that of the neighbouring Cader-Idris range. But, although Cader Idris itself has attracted the attention of several eminent geologists, little detailed work has been devoted to the foot-hill district on the north.

1847. A. Sedgwick.—'On the Clássification of the Fossiliferous Slates of North Wales' Q. J. G. S. vol. iii, p. 147.

The presence of the Ffestiniog [that is, the Upper Cambrian] Group beneath the contemporaneous porphyries of the Cader-Idris range is established.

1850. Publication of the Geological Survey 1-inch Map. Quarter-Sheet 59 N.E. Surveyed by A. C. Ramsay & A. R. Selwyn. (Revised 1855.)

The intrusive rocks are separated, and the transgressive character of the Crogenen porphyry is clearly displayed by the manner in which it encroaches upon a band of 'ashes', the Lower Basic Series. No boundary is drawn, however, between the Upper Cambrian and the Ordovician rocks, all the strata below the above-mentioned 'ashes' being indicated by a single colour.

1866. A. C. Ramsay.—'The Geology of North Wales' 1st ed. Mem. Geol. Surv.

Although he gives considerable space to the description of the rocks on Cader Idris, Ramsay makes but brief references to the ground north thereof, and these mainly concern the intrusive rocks.

Ramsay himself favoured the view that the volcanic rocks of Cader Idris were all of what was later termed 'Arenig'[1] age, though he acknowledged the possibility of some of them being Tremadoc (p. 30). The intrusive rocks were shown to be of two kinds: 'greenstone' and 'felspathic porphyry,' both kinds, although frequently transgressive, occurring in sill-like forms.

Attention is called to the Dolgelley–Llyn Gwernan Fault, and to the resultant repetition of both stratified and intrusive rocks.

1867 & 1868. T. Belt.—'On the *Lingula* Flags of Dolgelley' Geol. Mag. 1867, pp. 493 & 536; *ibid.* 1868, p. 5.

This classical paper gives an account of the lithology, palæontology, and general distribution of each of the three divisions of the *Lingula*-Flag formations as developed in the Dolgelley district. Each division is further subdivided into Lower and Upper portions. Two or three fossil localities are recorded in the area south of the Mawddach, but most of the fossils mentioned were obtained in the district north of Dolgelley.

1881. A. C. Ramsay.—'The Geology of North Wales' 2nd ed. Mem. Geol. Surv.

In the second edition of the Survey Memoir, beyond certain changes in the nomenclature of the groups, there is little additional to the first edition so far as the geology of the Dolgelley district is concerned. An account is, however, given of the grit-band which marks the base of the Arenig in the district east of Llwyngwril, but it is stated that '...... from this point [that is, a point 1¼ miles south-west of Arthog] all along the broken hills between the Mawddach and Cader Idris its position is quite unknown.'

1889. G. A. J. Cole & A. V. Jennings.—'The Northern Slopes of Cader Idris' Q. J. G. S. vol. xlv, p. 422.

Petrological descriptions of some of the rocks on Cader Idris are given. The felspathic porphyry of Llynau Crogenen was found to be a granophyre or 'eurite' similar to the acid intrusive rocks on Cader Idris itself. As regards the stratigraphy, the authors stated that 'until those best qualified to judge extend the local base of the Arenig to the northern front of Mynydd-y-Gader, a hill north of the Cader-Idris escarpment, we must regard a large portion of the eruptive series as of Upper or even of Lower Tremadoc age' (p. 437).

1896. P. Lake & S. H. Reynolds.—'The *Lingula* Flags & Igneous Rocks of ... Dolgelley' Q. J. G. S. vol. lii, p. 511.

This paper contains a geological map of the district immediately south and south-west of Dolgelley, on which the outcrops of the Ffestiniog, Dolgelley, and Tremadoc Beds are separated. It was shown that on Mynydd-y-Gader Tremadoc Beds yielding *Dictyonema sociale* were followed by a series of rhyolitic rocks. An igneous band in the Dolgelley Beds was described as a lava, and was stated to be associated with ashy beds.

1897. Sir Archibald Geikie.—'Ancient Volcanoes of Great Britain.'

On the evidence obtained by Prof. Cole & Mr. Jennings and by Mr. Lake & Prof. Reynolds, and also as the result of his own observations, the author gave it as his opinion that the volcanic activity started at least as early as Tremadoc time (p. 177).

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[1] Using the terms in the sense understood at the present day. No attempt is made in this paper to trace the changes of nomenclature as applied to the Upper Cambrian and to the Lower Ordovician rocks. The reader is referred to Prof. W. G. Fearnsides's paper on 'The Tremadoc Slates of South-East Carnarvonshire' Q. J. G. S. vol. lxvi (1910) p. 144.

1912. P. Lake & S. H. Reynolds.—'The Geology of Mynydd-y-Gader, Dolgelley' Q. J. G. S. vol. lxviii, p. 345.

This paper deals with the area immediately south of that previously described by the same authors. The rhyolitic rocks which succeed the Tremadoc Slates were found to be followed eventually by beds of Llanvirnian age. These latter were styled the 'Ashy Series', and were regarded as forming the upper portion of the Mynydd-y-Gader Volcanic Series. They consist of ashes and slates yielding *Didymograptus bifidus* (Hall) and *D. murchisoni* (Beck). Hence it was supposed that both Lower and Upper Llanvirnian Beds were there represented. The exact relation of the volcanic rocks to the Tremadoc Beds was however still obscure, since no Tremadoc fossils indicative of any higher horizon than the *Dictyonema* Zone had been found, nor were Ordovician fossils indicating any lower Zone than that of the *D.-bifidus* Beds obtained. The rhyolitic rocks were, however, found to rest transgressively upon or against the various divisions of the Upper Cambrian, and the apparent transgression was ascribed to faulting.

In 1912 one of us began an examination of the higher beds of the Cader-Idris range. During the progress of the work, it was found advisable to extend the investigation into the ground south of the Gwernan Fault and west of the area described by Mr. Lake & Prof. Reynolds. A preliminary report [1] on the results obtained from the examination both of this ground and of the main Cader-Idris area was presented at the Manchester meeting of the British Association in 1915.

The present paper contains a detailed description of the lower portion of the sequence outlined in that report.

II. The Stratigraphical Succession.

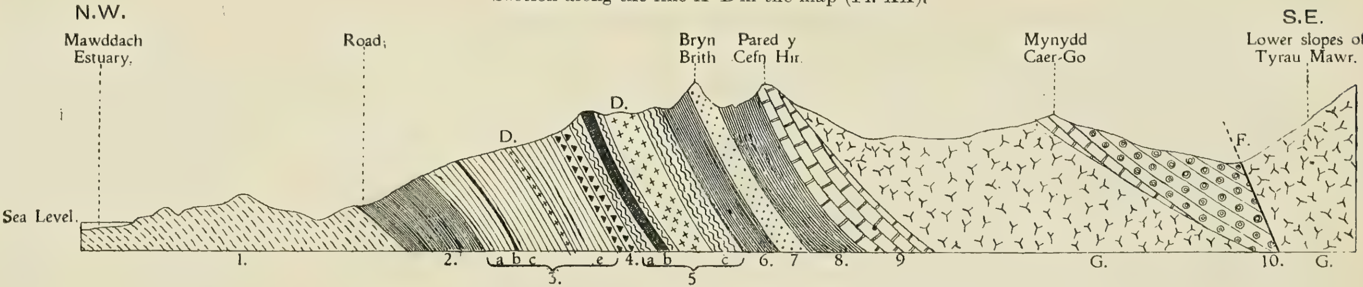
The general stratigraphical succession is as follows:—

? Llandeilo.	Lower Basic Volcanic Series.	
Lower Llanvirn.	Cefn Hir Ashes.	
	Crogenen Slates.	
	Bryn Brith Beds.	
	Moelyn Slates.	
	'China-stone' Ashes.	Lower Acid or Mynydd Gader Volcanic Series.
Lower Llanvirn and Arenig.	Pont Kings Slates.	
Arenig.	Lower Ashes.	
	Basement Series.	
	? Unconformity.	
Upper Cambrian.	Tremadoc Slates.	Upper Pencil-Slates. Upper *Dictyonema* Band *Asaphellus* Beds. Lower Pencil-Slates. Lower *Dictyonema* Band. *Niobe* Beds.
	Dolgelley Beds.	
	Ffestiniog Beds.	
	[Maentwrog Beds] (not seen south of the Mawddach Estuary).	

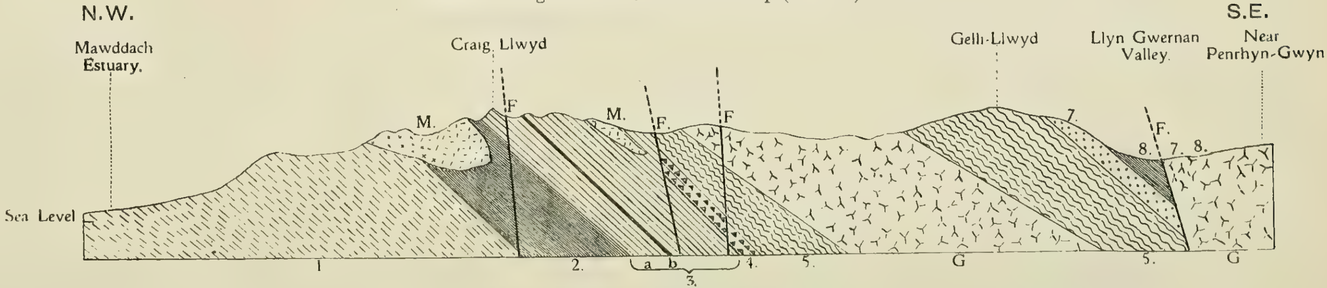
[1] A. H. Cox & A. K. Wells, 'The Ordovician Sequence on Cader Idris' Rep. Brit. Assoc. (Manchester, 1915) 1916, p. 424.

Fig. 1.—*Horizontal sections illustrating the geological sequence and structure in the Arthog–Dolgelley district.*

Section along the line A–B in the map (Pl. XX).



Section along the line C–D in the map (Pl. XX).



[Scales: horizontal & vertical. 3 inches = 1 mile.]

1 = Ffestiniog Beds.

2 = Dolgelley Beds.

3 = Tremadoc Slates.
- *a.* *Niobe* Beds.
- *b.* Lower *Dictyonema* Band.
- *c.* Lower Pencil-Slates.
- *d.* *Asaphellus* Beds.
- *e.* Upper Pencil-Slates.

4 = Basement Series.

5 = Lower Acid Series.
- *a.* Lower Ashes.
- *b.* Pont Kings Slates.
- *c.* 'China-stone' Ashes.

6 = Moelyn Slates.

7 = Bryn Brith Beds.

8 = Crogenen Slates.

9 = Cefn Hir Ashes.

10 = Lower Basic Series.

D = Diabase. M = Markfieldite. G = Granophyre (Eurite). F = Faults.

The correlation of the strata with those in other districts is discussed in a later section (§ V, p. 315). It may, however, be helpful to the reader to indicate at this stage that the Moelyn and Crogenen Slates together correspond to the main mass of the *Bifidus* Slates of other areas, also that the Cefn-Hir Ashes correspond to the Stapeley Ashes of Shropshire and to the Lower Andesitic Ashes of Arenig Mountain.

The various beds dip steadily southwards or south-eastwards at angles of 30° to 70°, so that a north-to-south traverse gives an ascending sequence. But the regular succession is somewhat disturbed by a few strike-faults which cut out certain groups of strata. It is further complicated by the presence of a number of intrusive masses, which, although generally sill-like in habit, yet transgress and accordingly cover up certain of the stratified rocks.

Detailed Description of the Succession.

(A) Upper Cambrian.

(1) The *Lingula* Flags.

It was in the Dolgelley district that the tripartite division of the *Lingula* Flags was first established by T. Belt.[1] The Maentwrog Beds—the lowest of these three divisions—occupy the ground on the north side of the Mawddach Estuary, but are not found on the south side.[2] The strata belonging to the other two divisions are fully represented. They appear, however, so similar to the corresponding beds elsewhere round the Harlech Dome, as (for example) in the Moel Llyfnant and Criccieth districts, where they have been fully described by Prof. W. G. Fearnsides,[3] that a detailed description here seems unnecessary, especially in view of the already existing accounts by Belt, and by Mr. P. Lake & Prof. S. H. Reynolds[4] of the beds in the immediate vicinity of Dolgelley.

The main points with regard to the lithology may, however, be briefly summarized as follows.

(i) The Ffestiniog Beds.—These consist here, as almost everywhere in North Wales, of a great series of greyish-blue flaggy slates interbanded with white laminated quartzite-bands and with fine-grained siliceous grits or 'ringers,' which often display the peculiar contorted or 'curled' bedding described by

[1] 'The *Lingula* Flags of Dolgelley' Geol. Mag. 1867, pp. 493, 536; and *ibid.* 1868, p. 5.

[2] For a recent description of these beds, see A. R. Andrew, 'The Dolgelley Gold-Belt' Geol. Mag. 1910, p. 165.

[3] 'The Geology of Arenig Fawr & Moel Llyfnant' Q. J. G. S. vol. lxi (1905) p. 612; and 'The Tremadoc Slates of South-East Carnarvonshire' *ibid.* vol. lxvi (1910) p. 142.

[4] 'The *Lingula* Flags & Igneous Rocks of the Neighbourhood of Dolgelley' Q. J. G. S. vol. lii (1896) p. 511.

Prof. Fearnsides.[1] The colour of the slates gradually changes, from grey in the lower part of the group to a bright blue in the upper part. They weather to a bright-green, sometimes becoming almost bleached. Joint-surfaces may be somewhat iron-stained. The more flaggy strata are often highly micaceous. The beds have yielded the characteristic *Lingulella davisii* at numerous localities.

The highest beds of the group are dark-blue slates, which eventually become lithologically similar to, and form a transition into, the Dolgelley Beds above. *Lingulella davisii* is particularly abundant in these highest beds, which are exposed on the roadside at Pont Aber-Gwynant. This highly-fossiliferous band is very characteristic of the top of the Ffestiniog Group, and it can be traced right round the Harlech Dome.[2]

The Ffestiniog Beds occupy a belt of country, averaging half a mile in width, all along the south side of the Mawddach Estuary. The ground occupied by their outcrop is generally very rough, and remains uncultivated on account of the resistant nature of the numerous grit-bands; most of the ground is densely wooded. East of the Gwynant the Ffestiniog Beds give rise to hills 600 to 800 feet high with a frontage (scarp) towards the estuary. West of the Gwynant they occupy lower, but still rough and densely wooded ground, with numerous precipitous little hills.

The thickness of the Ffestiniog Beds exposed along the Mawddach Estuary amounts to rather more than 2000 feet; but the base of the group is nowhere to be seen, as it lies buried beneath the alluvium of the estuary. The total thickness of the Ffestiniog Group in the Dolgelley district is estimated by Dr. Andrew at 3000 feet.[3]

(ii) The Dolgelley Beds.—The Dolgelley Beds represent here, as elsewhere, a much more uniform and deeper-water group of deposits than the Ffestiniog Beds. They consist of dark-blue to black mudstones, which are so highly pyritous that joint-surfaces become covered, especially in moist places, with a thick coating of iron-rust. Although the rocks are so uniform and fine-grained, the effects of cleavage are not usually sufficient to obliterate the bedding, which is shown in crag-exposures by a series of bedding-joints; nevertheless, small pieces do not split readily along the bedding. Occasional thin and pale-coloured seams of gritty material may be intercalated among the normal fine-grained dark mudstones. Near the centre of the group comes the well-known band with a black streak. About this horizon the mudstones usually show some lamination. The colour then becomes

[1] Q. J. G. S. vol. lxvi (1910) p. 150; also A. R. Andrew, Geol. Mag. 1910, p. 165; compare Bernard Smith, 'Ball or Pillow-form Structures in Sandstones' Geol. Mag. 1916, p. 151.

[2] W. G. Fearnsides, Q. J. G. S. vol. lxi (1905) p. 612; and *ibid.* vol. lxvi (1910) p. 152.

[3] Geol. Mag. 1910, p. 166.

little by little lighter and more grey-blue as the beds pass quite gradually into the overlying Tremadoc Slates. This transition is even more gradual than that from the Ffestiniog Beds to the Dolgelley Beds.

The characteristic fossil, *Parabolina spinulosa*, was obtained near Maes Angharad by Mr. Lake & Prof. Reynolds.[1] The same authors record other fossil localities on the northern flanks of Mynydd-y-Gader, where *P. spinulosa* Dalmann, *Orthis lenticularis* Wahl, etc. were obtained at Bryn-rhug. The *O.-lenticularis* Band has also been discovered in the Ceunant stream.

The whole group is much thinner than the Ffestiniog Group, having a thickness of about 600 feet.[2] Being much softer than the adjacent Ffestiniog and Tremadoc Beds, the Dolgelley Beds usually determine the position of a hollow, hence exposures, particularly of the black beds, are not abundant. The main road makes use of the hollow for some distance, and the black beds are seen in the road-cutting at the top of the steep hill above Arthog.[3]

(2) The Tremadoc Slates.

The Tremadoc Slates consist of a thick and rather monotonous series of slates and mudstones, usually grey-blue. It is, however, possible to distinguish in this slate-group a sequence which corresponds very closely indeed, as regards both lithology and palæontology, with that established by Prof. Fearnsides in the Arenig [4] and Tremadoc [5] areas.

[1] Q. J. G. S. vol. lii (1896) p. 516.

[2] An igneous rock occurs among the Dolgelley Beds where they are exposed along the northern flanks of Mynydd-y-Gader, and at Bryngwyn near Dolgelley town. Occasional ashy-looking beds are also developed among the normal dark slates. Mr. Lake & Prof. Reynolds regarded the igneous rock as an andesite-lava separating the Lower and Upper Dolgelley Beds (Q. J. G. S. vol. lii, 1896, p. 514). Followed westwards from the Dolgelley Fault, the rock thins out and disappears near the Derwas Fault. West of this fault no similar rock has been observed. Since, up to the present, no lavas have been proved to occur in the Dolgelley Beds of any other district, we prefer to regard the rock, which is in a very decomposed condition, as probably similar to some of the small intrusions that occur at frequent intervals in the Cambrian rocks north of the Mawddach. The horizon of the Dolgelley and Lower Tremadoc Beds seems to have been a favourite one for small intrusions, and, although no andesitic rocks are found west of the Derwas Fault, small diabase intrusions are frequent. Small andesitic intrusions have been shown by Prof. Fearnsides to be of frequent occurrence at the corresponding horizon in the Arenig country (Q. J. G. S. vol. lxi, 1905, p. 631).

[3] Near Garth Angharad and Pont Aber-gwynant the hollow is situated on the outcrop of Ffestiniog Beds, not of Dolgelley Beds. This is probably due to the rejuvenation of strike-streams which, originally flowing at a higher level in a hollow on Dolgelley Beds, have now cut down into the harder strata below. The rejuvenation eventually took place in stages, resulting in the production of 'benches,' which form narrow zones of fertile ground. The valley-cutting appears to have been practically completed before the close of the Glacial Period, judging from the manner in which boulder-clay is found deep down in the Gwynant Gorge.

[4] Q. J. G. S. vol. lxi (1905) p. 612; *ibid.* vol. lxvi (1910) p. 148.

[5] *Ibid.* vol. lxvi (1910) p. 157.

(i) The *Niobe* Beds.—As already remarked, the dark laminated shales of the Dolgelley Beds pass quite gradually into the paler and harder Tremadoc Slates. These lowest beds of the Tremadoc Series do not show any obvious lamination, and they are much less pyritous than the Dolgelley Beds, so that, although frequently assuming a red staining on weathering, they do not become covered with the very thick coat of rust that is so often seen in the Dolgelley Beds. In the course of about 200 feet the beds become harder and more flaggy, and the red staining becomes less pronounced. The uppermost flaggy beds are very fine-grained, and at first sight recall beds that have been baked by intrusions; they possess sometimes almost the appearance of a chert or an adinole, and weather completely white. They give rise to a marked escarpment on both sides of the Gwynant Valley: the one on the east side—Graig Llwyd—attaining a height of 1011 feet (Pl. XVI). At this locality *Niobe homphrayi* and various examples of *Lingulella lepis* Salter were obtained from the highest beds of the flaggy group. The characteristic fossil, *N. homphrayi*, was obtained by Belt from corresponding beds on the northern front of Mynydd-y-Gader.

(ii) The Lower *Dictyonema* Band.—Immediately succeeding the hard flaggy strata come the softer beds of the Lower *Dictyonema* Band. They consist of dark-blue shales passing up into harder blue-grey mudstones, which weather to a light grey. The soft beds determine the position of a hollow which is often very deep, as (for example) east of Garth Angharad. The fossils are usually to be found in the lower part of a small craggy scarp which overlooks this hollow, exactly as described by Prof. Fearnsides in the case of the corresponding beds of the Tremadoc district.[1] On the western bank of the Gwynant the small scarp is crowned by a wall, and numerous examples of *Dictyonema sociale* were obtained from the beds underneath the wall at various points between the river and the 350-foot contour. Higher up the hillside the *Dictyonema* Band is largely covered by screes from the overlying harder slates. The small scarp is also developed east of the river, and here again fossils were obtained from the lowest beds of the scarp at the point where it crosses the road. Farther east fossils were discovered at various points in the hollow immediately south of Graig Llwyd, just above (stratigraphically) the beds yielding *Lingulella lepis*; but at this last locality the *Dictyonema*-Beds are badly cleaved, and hence good specimens are difficult to obtain. The close association of *Lingulella lepis* and *Dictyonema sociale* is well-known elsewhere. Still farther east *Dictyonema* was found near Bron-y-gader by Belt,[2] and on the northern flank of Mynydd-y-Gader by Mr. Lake & Prof. Reynolds.[3]

[1] Q. J. G. S. vol. lxvi (1910) p. 157.
[2] Geol. Mag. 1867, p. 542.
[3] Q. J. G. S. vol. lii (1896) p. 514.

(iii) The Lower Pencil-Slates.—Following on the *Dictyonema* Band, the slates become less cleaved and less rusty as they pass upwards into a hard dark-grey mudstone. The ill-cleaved mudstone then passes upwards in the course of some 40 feet into blue slates, which usually take on a distinct 'needle' or 'pencil' cleavage. These latter beds sometimes contain in about the centre of the group partings and thin layers of quite coarse-grained gritty material.

(iv) The *Asaphellus* Flags and Shales.—The lower pencil-cleaved slates are succeeded by a group of hard flaggy beds more greyish and sometimes striped, though not markedly so, owing to the incoming of a certain amount of sandy material. Other bands are rather-bluer and highly micaceous. Nodules of cone-in-cone ironstone are occasionally to be found. Where there is not sufficient sandy material present to render the beds actually flaggy, then the rocks cleave into lenticular fragments, causing crags and weathered blocks to present a characteristic rubbly appearance. The rocks tend to weather white, but frequently are strongly iron-stained, often with iridescent films. Not infrequently also very black films may develop. This group of beds gives rise to a prominent feature (marked *d* on Pl. XVI) which runs almost continuously from one end of the district to the other.

Numerous fossils are obtainable from thinly-bedded micaceous flags or shales belonging to the upper part of the group exposed in trial-levels just beyond the north-western end of Llyn Wylfa. For a few feet the beds are here remarkably fossiliferous, rivalling the famous locality of Penmorfa; yet in levels only a few yards away from these highly prolific beds very few fossils are to be found. The fossils include:—

Asaphellus homphrayi Salter.	*Conularia homphrayi* Salter.
Agnostus calvus Lake.	*Centrotheca cuspidata* Salter.
Ormetopus prænuntius Salter.	*Theca* sp.
Lingulocaris sp.	*Obolella*.

(v) The Upper *Dictyonema* Band.—Above the flaggy *Asaphellus* Beds occurs a second band rich in *Dictyonema*.

The best and most easily accessible fossil locality is that on the western bank of the Gwynant, about 80 yards south of Pont Ty-gwyn. The *Dictyonema*-bearing strata here occupy the bed of the tributary rivulet (often dry), and they also give rise to screes on the steep bank above the roadway. Cleavage and bedding almost coincide, and *Dictyonema* is so extremely abundant that large slabs with surfaces entirely covered by the fossil may be obtained. Less commonly, specimens of *Callograptus* are to be found. The fossil occurs in grey-blue, somewhat flaggy slates that weather rusty at first, finally becoming greyish-white.

Fragments of *Dictyonema* were also obtained at a slightly lower horizon from baked beds on the north side of the diabase at Pont Ty-gwyn; therefore the fossil tends to occur through a considerable

thickness of beds. Unfortunately, the exact position of this second *Dictyonema* Band with regard to the *Asaphellus* Beds of Llyn Wylfa cannot be determined, as the strata that presumably include the *Dictyonema* Band are hidden beneath the lake and the bordering alluvium. There can be no doubt, however, that this second *Dictyonema* Band occurs stratigraphically above the *Asaphellus* Beds, and is therefore quite distinct from the first *Dictyonema* Band which lies well below the *Asaphellus* Beds.

(vi) The Upper Pencil-Slates.—The highest Tremadoc Beds in this district comprise a group of softer strata, with an irregular cleavage which causes the rocks to crumble into small fragments, or sometimes to split into long splinters or pencils. Fossils are hence difficult to obtain, and so far only a few specimens have been collected. *Bellerophon* sp. was obtained at a point on the south-east side of Llyn Wylfa close underneath the basal grit of the Ordovician, and a solitary example of *Asaphellus (?)* from a locality a few yards north of the Waen-Fechan sill. Owing to the lack of fossils, it remains uncertain for the present as to whether these beds represent the *Angelina* Beds of other areas.

The total thickness of the Tremadoc Slates, as developed in the Dolgelley district, amounts to a little over 900 feet. The correlation of the beds is discussed in a later section (§ V, p. 315).

Relation of the Ordovician to the Cambrian Strata.

Throughout the western part of the district mapped, the Tremadoc Slates are overlain by a grit which forms the local base of the Ordovician strata. The change in the type of deposit takes place quite abruptly. The sudden change may indicate a break between the two series, but the evidence so far obtained does not suffice to prove the presence of an actual unconformity. In the first place, the exact dip of the higher beds of the Tremadoc Slates cannot, as a rule, be determined owing to cleavage. Therefore, even in the case of good exposures, it becomes impossible to ascertain whether or no there is actual discordance between the dip of the slates and that of the overlying grits. It is, however, certain that if there is any discordance it can only be very slight. Secondly, although the junction has been mapped over a distance of several miles, the mapping has failed to demonstrate the presence of an unconformity. It is true that over more than half the distance evidence on this point is lacking, owing to the prevalence of faults and intrusions. Allowing for such disturbances, however, the exposures are clear over a distance sufficient to show that there can be no great discordance of dip and strike between the two series. The relationship between the Cambrian and the Ordovician Systems in the Arthog district is, therefore, comparable with that which obtains in the Arenig district, where the unconformity is so slight that its presence was only proved by detailed mapping over

a large area.[1] This stands in strong contrast with the relations obtaining farther north-west in the Lleyn peninsula, where there is a rapid transgression of the Arenig Grit across all the members of the Cambrian System, and the discordance is so great that the unconformity can be clearly seen in cliff-sections.[2]

Through the region farther east and nearer Dolgelley the relationship between the Ordovician and the Cambrian Systems must remain uncertain for the present, owing to the great prevalence of faults and of intrusions. Throughout this part of the district the Cambrian and Ordovician rocks are invariably separated one from the other by diabase-intrusions. Mr. Lake & Prof. Reynolds [3] have shown that eastwards along Mynydd-y-Gader there is a progressive increase in the amount of the Cambrian strata that are cut out by the intrusion, so that, first the Tremadoc, and later the Dolgelley Beds, disappear; while we find that still farther east, in the Aran Valley, the basal Ordovician beds rest in close proximity to beds well down in the Ffestiniog Group. The absence of the higher Cambrian beds is undoubtedly due in part to the presence of a strike-fault—the Mynydd-y-Gader North Fault (see p. 312); we find that all the strike-faults in this district increase in throw to the eastward (p. 313), so that absence of a greater thickness of Cambrian rocks to the east may possibly be due entirely to faulting. At the same time, one of us (A. K. W.), working in the country north-east of Dolgelley, finds some evidence pointing to the presence of a considerable unconformity in that direction. Thus the absence of Tremadoc Beds in the country south-east of Dolgelley may be due in part to an unconformity, and only in part to faulting.

(B) Ordovician.

(1) Arenig: The Basement Series.

The Ordovician strata begin with a series of arenaceous beds, grits and sandy flags, resting on the underlying Tremadoc Slates without any evidence of transition, the junction between the two groups of strata being quite sharp.

The Basement Series is perhaps best seen on the slopes south of Llyn Wylfa, while the junction with the Tremadoc Slates is clearly displayed south-east of the eastern end of the lake. The lowest members of the group here consist of well-stratified grits in beds 2 to 4 feet thick. The dip of the grits is about 40° south-south-eastwards; but, as the dip of the Tremadoc Slates cannot be made out owing to cleavage, it is impossible to say whether there is any actual discordance.

The lowest grits are generally dark grey, highly felspathic, and hence rather ashy-looking, though in places they become bluer,

[1] W. G. Fearnsides, Q. J. G. S. vol. lxi (1905) p. 618.
[2] T. C. Nicholas, *ibid.* vol. lxxi (1915) p. 139.
[3] *Ibid.* vol. lii (1896) p. 511.

less felspathic, and more like a quartzite. Their texture is usually medium to rather fine-grained, and true pebbles are wanting, though small pellets of mudstone, possibly derived from Tremadoc Slates, are fairly abundant in the actual basal bed.

Some 10 to 15 feet up in the series argillaceous material begins to make its appearance, distributed in thin shreds and streaks; these increase in amount upwards, and so give rise to a set of streaky grits that are highly characteristic of the Basement Series. The striping of the grits is at first irregular, owing to the lenticular arrangement of the alternations of arenaceous and argillaceous material, the latter being distributed in thin films that curve round the sandy lenticles in a manner suggestive of ripple-marking and false bedding. The sandy material is sometimes white, sometimes grey, or almost blue, according to the amount of chloritic matter present.

Still higher up the argillaceous partings increase in number, and at the same time the alternations of sandy and muddy material become much more regular and more closely spaced; this gives rise to a group of flags with very regular striping. The sandy material is now almost invariably pale-coloured, and is also rather finer-grained than in the irregularly-streaked grits below. Among these regularly-banded flags is intercalated a massive band of white fine-grained grit which has almost the character of a true quartzite. It is overlain by a small thickness of flags similar to those below.

The group is terminated upwards by about 6 feet of slates. The slates are themselves somewhat flaggy, owing to their micaceous and slightly arenaceous character. They are dark bluish-grey, and contain a fair amount of pyrites. Being so thin the slate-band is not often exposed, but it is well seen at the point where the stream issuing from Llynau Crogenen crosses the outcrop of the Basement Series. The junction of the slates with the massive rhyolitic rocks above is here excellently displayed.

The streaky grits and the banded flags are constant members of the Basement Series; but the actual basal grits, such as those seen near Llyn Wylfa, are not always developed. Nor is the higher massive white quartzite invariably present: for example, it seems rather impersistent near Llyn Wylfa. The Basement Series has a thickness of 150 to 200 feet.

These basement beds frequently occur on the slopes of a steep scarp overlooking the Tremadoc Slates, the top of the scarp being occupied by the rhyolitic rocks of the Lower Acid Series with their attendant diabases. For this reason outcrops are often obscured by screes from above. This is the mode of occurrence for the whole distance between Llyn Wylfa and the stream issuing from Llynau Crogenen. Near this stream are good exposures. Still farther west other good exposures occur on each side of the Arthog Glen and Waterfalls, on the east side especially near Pant Phylip, and on the west side near Crogenen Farm and at the edge of the wood above Arthog-Hall Hotel. In this neighbourhood the outcrops are affected by an anticlinal fold, and they are

slightly displaced by faulting, the faults being a continuation of, or branches from, the Llyn-Bodlyn Fault north of the Estuary. Immediately west of the glen the beds escape from the anticline with an abrupt change of strike, so that they form the rough hills above Arthog Terrace, and thence, resuming the normal south-westerly strike, continue for half a mile parallel with, and alongside, the main road as far as Capel Horeb (about half a mile south-east of Barmouth-Junction Station). The beds are here affected by a shallow north-and-south synclinal fold, complementary to the anticline previously mentioned. The gentle folding is clearly displayed in the run of the ridges as viewed from Barmouth Bridge. Along the above-mentioned half-mile stretch the Basement Series is bordered by the alluvium of the estuary, and the base of the Ordovician is here only $1\frac{1}{4}$ miles distant from the outcrop of the Lower Cambrian rocks at Barmouth.[1]

Near Capel Horeb the south-westerly strike carries the outcrop inland once more towards Cyfanydd.[2] The further continuation of this line is shown on the 1-inch Geological Survey map[3] passing about $1\frac{1}{2}$ miles east of Llwyngwril, and gradually swinging round to an almost north-and-south direction until it finally disappears under the alluvium of the Dysynni Valley near Llanegryn, $3\frac{1}{2}$ miles north-north-east of Towyn, and 8 or 9 miles south-south-west of Llyn Wylfa.

On both sides of the Arthog Valley the strata of the Basement Series are intimately associated with diabase intrusions which generally obscure the junction with the Tremadoc Slates below. Grits and diabases, together with the overlying rhyolitic rocks, give rise to rough and often densely-wooded ground, scarred by numerous crags and screes. Such ground offers a marked contrast to the smoother ground occupied by the higher part of the Tremadoc Slates. The difference is well seen from near Barmouth Junction, whence the course of the Upper Tremadoc Slates south-westwards can be readily picked out, by reason of the line of green fields below the rough rock-strewn and wooded slopes occupied by the Ordovician strata.

West of Llyn Wylfa the Basement Series can be followed, as described above, without interruption for a distance of over 9 miles. Immediately east of the lake, however, the series disappears under the Cae-Einion diabase, and is cut out by the Derwas Fault (p. 311), so that it does not appear in the Gwynant Valley, and it is not again seen for a distance of $1\frac{3}{4}$ miles, until the neighbourhood of Maes Angharad is reached. Here the characteristic banded flags emerge from the alluvium for a short space. The band probably continues eastwards past Llwyn Iarth, where, however, it becomes concealed owing to the rapid spreading of the diabase intrusion.

[1] A. R. Andrew, Geol. Mag. 1910, p. 167.

[2] About 1 mile east of Fairbourne Station, beyond the western boundary of the map, Pl. XX.

[3] Old Series, 1-inch, Sheet 59 N.E.

The band is then shifted north-eastwards by the Dolgelley Fault. East of the fault the beds are well seen on the south side of the diabase intrusion that runs immediately south of Dolgelley town. Throughout this part of their course the more shaly layers are often burnt and spotted by the neighbouring intrusions. After crossing the Aran stream just above Dolgelley, the outcrop is once more interrupted by faulting—the Ceunant Repeating Fault—causing the beds to reappear a mile farther up the Aran Valley.

The fact that the beds have not been recognized by previous observers within the district now mapped is probably accounted for by reason of the mode of occurrence of the strata: they are either intimately involved among diabase intrusions, or else they are covered by screes from the rhyolitic rocks above, while over long stretches they are entirely cut out by faulting, as, for example, along the northern slopes of Mynydd-y-Gader.

No fossils, other than worm-tracks and some quite indeterminable graptolites, have been obtained from this arenaceous series. But there can be no doubt that we are here dealing with the local base of the Arenig: the stratigraphical position of the series and its characteristic lithology furnish evidence enough. It will be noticed that the lithology corresponds almost exactly with that of the Basal Grit and *Extensus* Flags of Arenig,[1] and with the Tudwal Sandstones of the Lleyn Peninsula.[2]

(2) Arenig (and Lower Llanvirn): the Lower Acid, or Mynydd-y-Gader Rhyolitic Series.

The arenaceous strata of the Basement Series are immediately overlain by a series of rhyolitic rocks. The series takes its name from Mynydd-y-Gader, a hill south-east of Llyn Gwernan, where the rhyolitic nature of the rocks was first determined by Mr. Lake & Prof. Reynolds.[3] These authors found that both rhyolitic lavas and rhyolitic ashes are represented, and that the lavas tended to thin out and disappear when traced from east to west. The westward thinning of the volcanic rocks continues, and becomes still more pronounced in the area at present under consideration, where the series is represented almost entirely by rhyolitic tuffs, lavas being only doubtfully present at one or two points.

West of the Gwynant, moreover, definite slate-bands appear within the rhyolitic series, so that the sequence there seems at first sight rather different from that on Gelli-llwyd and other localities east of the Gwynant and nearer to Mynydd-y-Gader. It is evident that considerable changes take place as the beds are followed along the strike; but, between the Gwynant Valley and Gelli-llwyd, the outcrop of the rhyolitic rocks is interrupted by a granophyre sill, and accordingly the exact gradations of the lateral changes are not easy to follow. For this reason, it will be most convenient to

[1] Q. J. G. S. vol. lxi (1905) p. 618.
[2] *Ibid.* vol. lxxi (1915) p. 108.
[3] *Ibid.* vol. lii (1896) p. 516.

describe first the characters and sequence of the rocks as exposed west of the Gwynant, where the series is thinner and its age can be more readily determined by means of the included slate-bands.

(*a*) The development west of the Gwynant Valley.—West of the Gwynant the Lower Acid Series consists of three well-marked subdivisions:—

(iii) 'China-stone' Ashes.
(ii) Pont-Kings Slates.
(i) Lower Ashes.

This sequence remains practically constant, from the Gwynant Valley on the east to the Arthog Valley on the west. But, although the sequence remains the same, the westward thinning of the rhyolitic rocks themselves continues, and accordingly the slate-beds appear to play a much more important part in the west than they do in the east.

(i) The Lower Ashes.—Massive rhyolitic rocks succeed the arenaceous rocks of the Basement Series quite abruptly. The junction most clearly exposed is the one already mentioned as situate on the banks of the stream flowing from Llynau Crogenen to join the Afon Arthog.

Among the rhyolitic rocks themselves various lithological types may be distinguished, the differences being sometimes sharply marked, while in other cases the varieties seem to grade one into the other. The rocks are all essentially acidic, the variations being due solely to the variable amounts of pumice-dust and of pyroclastic felspar-crystals that go to make up the strata, or to the admixture of these volcanic products with varying amounts of argillaceous material.

One of the most commonly occurring types, especially prominent in the lower and middle portions of the series, forms massive beds made up largely of small broken felspars accompanied by small and scattered quartzes, embedded in a more or less abundant matrix of rhyolitic dust. Such rocks, on weathering, yield rough joint-surfaces which show a rather irregular lamination that may simulate flow-structure. Fractured surfaces are frequently somewhat iron-stained, but joint-surfaces weather white or cream-colour after the usual manner of rhyolitic rocks. Such massive rocks may or may not show the effects of cleavage. Associated with the massive rocks, but not so abundant, are well-cleaved ashes that weather into thin papery leaves. The leaves are strongly iron-stained, although joint-surfaces weather white in the usual manner; joint-surfaces in these well-cleaved rocks are smooth, not rough as in the massive rocks described above. As regards their composition the better-cleaved rocks consist almost entirely of the finest rhyolitic dust, distinct broken crystals and recognizable fragments being absent; but the one type grades into the other.

Another type consists of fine-grained ashes resembling the 'China-stone' Ashes to be described below (p. 272). These rocks break with a smooth conchoidal fracture, giving sharp-edged splinters in exactly the same manner as flint. They do not weather so deeply as the types described in the preceding paragraph, but eventually they, too, give rise to a white crust similar to that of the other rhyolitic rocks. Fresh surfaces may show a beautiful and regular colour-banding which is especially prominent where the ashes are

in the near neighbourhood of diabase-intrusions. A very small degree of contact-metamorphism evidently suffices to emphasize the slight differences in composition between the various bands. With the incoming of coarse material these fine-grained ashes pass over into the massive type already described. On the other hand, they may pass by a rapid transition into almost normal slates.

In places the more roughly-weathering, rather felspathic ashes include peculiar lumps and strings of fine-grained 'china-stone' ash, which may be seen, for example, in the thin middle ash-band exposed in the fault-gully east-north-east of Bryn Brith. This phenomenon is important, as it represents the first incoming of the peculiar 'agglomeratic' type of rocks that attains a much greater development in the Rhyolitic Series east of the Gwynant, and at a somewhat higher level in the Bryn Brith Beds. (See *postea*, p. 275.)

Another type consists of a blue rock resembling the 'China-stone' Ashes in possessing a splintery conchoidal fracture like that of flint, but differing from them in that no lamination is visible in the hand-specimen. Also the non-laminated rocks, unlike the 'China-stone' Ashes, show no tendency to pass over into slates; they usually occur in very thick beds, and, although themselves massive, they are frequently separated one from the other by thin films of soft well-cleaved ashy material, after the manner often seen among rhyolitic flows. The weathered surface is, as usual, white. Rocks of this type are best developed low down in the Volcanic Series. It is possible that some of these rocks may represent actual rhyolite-flows rather than ashes, and the same hypothesis may even apply to certain of the cream-coloured rocks. No single example of either type has, however, shown any of the special characteristics, such as spherulitic or perlitic structures, or the contorted flow-lines, that would enable one to identify a rhyolite-lava with certainty. Since there exist clear transitions from the cream-coloured rocks into rocks that are undoubtedly ashes, while there also appear to be other transitions from the cream-coloured rocks to the flinty types, it may well be that the whole of the rhyolitic rocks consist of nothing but ashes, and that no true flows are present.

We find, however, that elsewhere, as, for example, on Mynydd-y-Gader, true rhyolites belonging to the Lower Acid Series often present an extraordinary resemblance to tuffs. In one case a rock, that at first sight appears to be a cleaved tuff passing over into ashy slates, suddenly develops a nodular structure, and is then obviously a typical nodular rhyolite. Another well-cleaved example, which in a small exposure exactly simulates a cleaved ash, is seen, when well exposed along a large dip-joint face, to possess a broad and rather irregular flow-banding cut across obliquely by the cleavage.

Seeing that such cases occur on Mynydd-y-Gader, it is quite possible that in the westerly extension of the same series, some of the rocks which appear to be ashes, may really be lavas. The difficulty of distinguishing between rhyolite-flows and rhyolite-tuffs is, of course, no new one, having been met with frequently in other districts.

The question of the existence of actual rhyolitic flows is, however, of minor importance in this case. The essential feature of the Lower Acid Series is that the volcanic emissions were most markedly acidic in character, and do not contain any bands of trachytic or andesitic composition.[1] In this respect they offer a

[1] In the area east of the Gwynant certain agglomerates in the Lower Acid Series do contain blocks of highly-vesicular lava of almost basic composition (see p. 273); but it still remains true that no definite bands entirely composed of trachytic or andesitic material are to be found.

marked contrast to the ashes of the Upper Acid Series of Cader Idris.[1]

In thin section the massive rocks of the Lower Acid Series prove very disappointing. When viewed in natural light sections appear quite featureless; while, as seen between crossed nicols, the rocks are uniformly cryptocrystalline with only occasional quartz and felspar phenocrysts, which are more abundant but less idiomorphic in those rocks that are obviously ashes than in those that may represent flows. Faintly-pleochroic chlorite, occasional leucoxene, and minute zircons may be present as accessories. No trace of perlitic or spherulitic structure has been observed. It is also worthy of note that none of these rocks appear to show the 'aschen-struktur' that is so frequently found in quartz-keratophyre tuffs. They probably consisted originally of the very finest dust of glassy material.

A noteworthy feature of the Lower Acid Series in the field is the persistency with which, throughout its outcrop, the strata have been invaded by diabase intrusions. The intrusions, while generally sill-like in form, often bear rather peculiar relationships to the stratified rocks, the details of which will be described below (p. 281). Where the volcanic series is comparatively thin, as in the area east of the Gwynant, there are usually a number of separate but small intrusions. Individual intrusions may be only a few feet thick, and yet may be followed along the strike over distances surprisingly great.

(ii) The Pont Kings Slates, and the age of the Lower Acid Series.—Interbedded among the rhyolitic rocks in the western part of the area are two bands of slate, here termed the 'Pont Kings Slates.' The slate-bands are separated one from the other by typical rhyolitic ash, while the upper slate-band itself contains thin bands of rhyolitic ash, and is followed by massive ashes. This sequence can be followed over a distance of 2 or 3 miles, and in numerous places all the junctions are well exposed. There is, then, no room for doubt that it is a true stratigraphical sequence, and that the slates are interbedded among the rhyolitic rocks.

The slates are of a rather dark blue, and they weather somewhat greyish. Cleavage is well developed, though not sufficiently so to render the beds workable for slates. A sort of incipient concretionary structure is common, and the manner in which the slate splits into large but thin sheets with rather irregular surfaces, recalls closely what is seen in the *Tetragraptus* Beds of South Wales and Shropshire.

Fossils are scarce as a rule, though locally certain species may be very plentiful. The general scarcity of fossils is the more unfortunate, since these slates appear to contain the junction of the Arenig with the Llanvirn Series. Numerous graptolites were obtained from the lower slate-band where it gives rise to a small tump on the 1000-foot contour-line, due south of Garth Angharad and about a quarter of a mile west-north-west of Llyn Pen-Moelyn. They included *Didymograptus nitidus* (Hall), small forms of

[1] A. H. Cox & A. K. Wells, 'The Ordovician Sequence in the Cader-Idris District (Merioneth)' Rep. Brit. Assoc. (Manchester, 1915) 1916, p. 424.

D. bifidus (Hall), and *Climacograptus scharenbergi* Lapworth. *Didymograptus nitidus* was also obtained from the same slate-band on the crags due south of Llyn Wylfa, and fragments of extensiform graptolites from one or two points elsewhere. *D. bifidus* and *Cl. scharenbergi* were also found in corresponding slates on the eastern bank of the Gwynant opposite the islet at Pont Kings. All the localities mentioned are in the lower of the two slate-bands.

There is no question that the early forms of *Didymograptus bifidus* do occur in actually the same beds as the extensiform graptolites. It is fairly certain, therefore, that we have here the junctions of the zones of *Didymograptus hirundo* and *D. bifidus*, or, in other words, the junction of the Arenig and the Llanvirn Series, and that the lower half of the Pont Kings Slates is to be referred to the Arenig and the upper half to the Llanvirn Series.

Since there is no doubt that the slates form a true intercalation in the Lower Acid Series, it follows that the volcanic series begins in, or just below, the zone of *Didymograptus hirundo*, and continues up into the lowest part of the Llanvirn Series, closing with the formation of the 'China-stone' Ashes and associated rocks that immediately overlie the Pont Kings Slates. The representatives of the volcanic series in other districts will be discussed below (see pp. 316 & 318).

(iii) The 'China-stone' Ashes.—Succeeding the higher of the two Pont-Kings Slate bands comes a well-marked band of ash. The ashes belong predominately to the 'china-stone' type: that is, they are very fine-grained rocks, and break with a smooth conchoidal fracture into sharp-edged chips. When fresh they are blue-hearted, but they yield the usual white crust on weathering. The colour is sometimes constant over a considerable thickness of rock; at other times a mottling following the lamination makes its appearance. With the incoming of coarser material they pass over into creamy types of rhyolitic ash, such as those already described (p. 269). On the other hand, all transitions to normal slates may be present within a small thickness of rock.

These rocks are well exposed along the roadside at Pont Kings, and thence almost continuously right away to the Arthog Valley. They resemble in all respects, and are probably on the same horizon as, the ashes that occur at or near the base of the *Didymograptus-bifidus* Zone in Shropshire,[1] and at various localities in South Wales.[2] The petrology of the similar rocks of South Wales has been described by Dr. H. H. Thomas, and also by one of us.[3]

[1] C. Lapworth & W. W. Watts, 'The Geology of South Shropshire' Proc. Geol. Assoc. vol. xiii (1894) p. 317.

[2] D. C. Evans, 'On the Ordovician Rocks of Western Carmarthenshire' Q. J. G. S. vol. lxii (1906) p. 613; T. C. Cantrill & H. H. Thomas, 'The Geology of the Country round Carmarthen' Mem. Geol. Surv. 1909, pp. 24 & 25; J. Pringle & others, 'Final Report on the Geology of Ramsey Island' Rep. Brit. Assoc. (Australia) 1914, p. 111; A. H. Cox, 'The Geology of the District between Abereiddy & Abercastle' Q. J. G. S. vol. lxxi (1915) p. 298.

[3] Q. J. G. S. vol. lxxi (1915) p. 299.

(*b*) The Lower Acid Series east of the Gwynant.—East of the Gwynant the Lower Acid Series increases considerably in thickness, owing to the much greater development of the rhyolitic ashes. At the same time the slate-bands (the Pont Kings Slates) dwindle away rapidly, and finally disappear altogether, and thus eventually the series consists entirely of a great thickness of rhyolitic rocks with practically no slate-intercalations. This aspect of the volcanic series is, therefore, very different from that which obtains west of the Gwynant.

The Pont Kings Slates, already thinning considerably, dive under the granophyre a little east of Pont Kings itself, never to reappear in the country farther east, although the associated rhyolitic rocks can be followed to and beyond the Aran Valley, a distance of 3 miles.[1] The inference is, therefore, that the slates have died away through attenuation against a volcanic pile.[2] It is true that, owing to the presence of intrusive rocks and faults, the volcanic series is never seen in its entirety east of the Gwynant: that is, neither on Gelli-llwyd, nor on Mynydd-y-Gader, nor nearer Dolgelley. Accordingly, the evidence for the dying-out of the slates is to some extent incomplete. Still, it is very unlikely that, if really present, they should be concealed over the whole 3 miles to the Afon Aran. Therefore, when account is taken of the observed thinning of the slates and thickening of the volcanic rocks, together with the extent to which the latter rocks are exposed, the absence of the slates appears fairly certain.

Among the rhyolitic rocks east of the Gwynant, examples of all the various types already described as being present west of the river may be found. Also some new types make their appearance. The most prominent of these new rocks are agglomeratic in character. The agglomerates occur at both the top and the bottom of the volcanic series. The fragments are of all sizes up to 1 foot in diameter, and consist of rhyolites as also of vesicular rocks of more andesitic composition. Actual andesitic lava-flows do not occur within the area described, therefore the fragments must have come from some neighbouring district; but, in view of their large size, the source of origin could not have been very far distant, and, taking into account the north-eastward thickening of the volcanic series, we are inclined to consider that their point of origin is to be sought towards the Rhobell-Fawr area. Further reference will be made to this question (see p. 316).

Other rock-types that make their appearance in the volcanic series east of the Gwynant are grits. The grits occur only in thin bands, and are seen but

[1] It is true that slate-bands are recorded by Mr. Lake & Prof. Reynolds (Q. J. G. S. vol. lxviii, 1912, p. 347) as occurring among the 'Ashy Series' of Mynydd-y-Gader; but it should be noted that the Lower Acid Series, as defined in the present communication, does not include all the strata described by those authors under the term 'Ashy Series.' The slates mentioned by them are here referred to the *Didymograptus-bifidus* Beds, or to beds still higher in the stratigraphical succession.

[2] It will be shown later that another and higher slate-band, the Moelyn Slates, also thins out against the volcanic pile (see p. 274 & fig. 2, p. 277).

locally. One such band occurs low down in the series, and is well exposed on the path south of Waen Fechan, where it is in contact with the southern edge of the diabase sill. It consists of a massive, streaky, well-laminated, ashy dark-grey grit, and only giving a thin pale film on weathering. It is both underlain and overlain by the normal, massive, fine-grained rhyolitic ashes.

Higher up in the volcanic series occur two bands of felspathic grit, each about 6 feet thick. These grits are greenish-grey, and closely resemble some of the grits in the Bryn Brith Beds. One of the bands is seen on the 900-foot tump, near the granophyric marginal rocks, on the north-eastern flank of Gelli-llwyd; while the higher band is exposed immediately south-east of the diabase that forms the eastern summit of Gelli-llwyd, and north-east of the two small faults that cut the diabase.

None of the three grit-bands can be traced more than a few yards, owing to the presence of intrusive rocks; but the fact that they have not been found west of the Gwynant suggests that they rapidly die out in a lateral direction.

(3) Lower Llanvirn.

(i) The Moelyn Slates.—A band of slate succeeds the 'China-stone' Ash that, west of the Gwynant, marks the top of the Lower Acid Series. The slates are well exposed near Llyn Pen-Moelyn, on the northern flanks of Bryn Brith, and generally speaking throughout their course between the Gwynant and Arthog Valleys, despite the fact that the beds determine the position of a marked hollow. The Moelyn Slates are of a rather darker blue than any of the slates below, and they contain a good deal of pyrites, wherefore scree-material is often strongly iron-stained. The rocks are well cleaved, giving smooth cleavage-slabs, and they exactly resemble the slates low down in the *Didymograptus-bifidus* Beds of Pembrokeshire. They have been prospected for slates on Bryn Brith, on the banks of the stream that issues from Llynau Crogenen, and elsewhere; but they have nowhere actually been quarried. The band varies in thickness from 40 to 50 feet in the Arthog Valley to about 150 feet on Bryn Brith.

East of the Gwynant the Moelyn Slates are cut out by the granophyre-sill, and, except over a short stretch in the Gwynant gorge, they do not reappear on the south side of the intrusions, since they (like the Pont Kings Slates below) thin out against the volcanic pile of Gelli-llwyd.

Fossils are not numerous, possibly in part owing to the strong cleavage. It is, however, often the case in other districts, that the lower part of the *Didymograptus-bifidus* Zone is not very fossiliferous. The Moelyn Slates yielded *D. bifidus* at several localities near Llyn Pen-Moelyn, and on the right bank of the Gwynant immediately south of the granophyre-sill. *Orthoceras* cf. *caereesiense* Hicks was obtained from slates near Llyn Pen-Moelyn.

(ii) The Bryn Brith Grits and Ashes.—Intercalated among the *Bifidus* Slates are the Bryn Brith Beds, a group of peculiar ashy grits. The grits themselves contain much (more or less silicified) argillaceous material, distributed in such a manner that the rocks often assume an agglomeratic appearance. The

total thickness is about 150 feet, but is somewhat variable from place to place. In the lower part of the group occurs a well-marked band of slate 20 feet thick, exhibiting the normal characters of the *Bifidus* Slates. This slate-band yielded *Didymograptus bifidus*, along with fragments of extensiform graptolites, at a small trial-level on the western bank of the Crogenen stream. The matrix of the main body of the rocks consists of greenish-grey ashy or gritty particles of a medium degree of coarseness, the constituents having diameters up to 1 or 2 mm. The ashy or gritty particles are cemented in a thin paste of argillaceous material, which locally increases considerably in amount.

These gritty rocks sometimes exhibit, when weathered, a well-marked and regular lamination, and they may also show the effects of cleavage; the lowest band of grits, below the slate-band, possesses these characters in a marked degree. On the other hand, the lamination may also disappear in the more massive types of grit, while at the same time the rocks yield but little trace of cleavage. Such massive rocks are well jointed, and break down into great rectangular blocks in the same manner as do many of the diabases of the district. In fact, the deceptive resemblance to diabase has evidently misled previous observers on more than one occasion. Another feature that aids in the deception is the frequently-occurring pseudo-vesicular appearance, due to the weathering-out of some of the constituents, leaving hollows which may eventually become infilled with calcite or some other secondary mineral.

As the gritty series is ascended there is a constantly-increasing tendency for a peculiar lithological type to make its appearance. It consists of argillaceous material more or less completely silicified, in such a manner that all transitions may be seen from dark, rather hard but otherwise normal, slaty material, to highly-silicified rocks which are harder than steel, possess a splintery fracture, and are closely comparable in appearance with the 'China-stone' Ashes at the top of the Lower Acid Series.

If the nature of this material is sufficiently peculiar, its mode of occurrence is even more so. It occurs sporadically distributed in the grits in patches that vary in size from small rounded pellets with diameters of less than a quarter of an inch, up to great irregular lumps and lenticular masses 1 foot thick and 2 or 3 feet long. Usually, the silicified material stands out prominently on weathered surfaces, since its smooth white crust shows up in sharp contrast with the rougher and greyer surface of the normal grits. It is this feature that accounts for the characteristic agglomeratic appearance of the beds in which it is found. Occasionally, however, the argillaceous material weathers away, leaving a more or less irregular cavity.

The amount of slaty matter varies rapidly from bed to bed, and even within the limits of a single bed. It may form more than half the total bulk of rock, or it may be absent altogether, or occur sporadically in the grit in isolated and irregularly-distributed masses. As a rule, it may be said that the smaller the masses are the more intense is the silicification, resulting in a rock which, by itself, would be mistaken for a rock derived from a china-stone ash or even from a rhyolite. Certain beds, therefore, that are mainly composed of small 'pebbles' of silicified material with the ashy matrix quite subordinate in amount, may easily be mistaken for a rhyolitic ash or agglomerate. One such bed occurs almost at the top of the Bryn Brith Beds, on Bryn Brith itself.

The larger masses, on the other hand, partake increasingly of the characters of normal mudstones or slates, and in the case of the largest they show the usual cleavage effects. Such large masses tend to be lenticular in shape, the elongation being usually in the direction of bedding, in such a way as

occasionally to give rise to distinct slaty beds. Examples have been observed, however, in which the maximum elongation of the slaty patches followed the cleavage, and cut across the bedding quite obliquely. Such cases appear to be exceptional, and their present position is due to distortion under the cleavage stresses.

The silicified 'pebbles' continue for a foot or two, up into the overlying Crogenen Slates, in which, however, the pebbles are set in a matrix of normal slaty material, instead of in the ashy gritty material characteristic of the Bryn Brith Beds themselves.

Coming between two slate-bands, the ashy grits of the Bryn Brith Group give rise to a distinct feature, which often develops into a prominent escarpment. This escarpment forms, on Bryn Brith itself, at an altitude of 1259 feet, the highest point within the area mapped. Along the narrow scarp-ridge which culminates in Bryn Brith, the dip-slope, as well as the scarp-slope, is largely bare rock, owing to the steepness of the dip, which is about 60°.

The actual sequence among the Bryn Brith Beds as seen on Bryn Brith itself, remains remarkably constant all the way from the Arthog Valley to a point immediately east of Llyn Pen-Moelyn. There is then a break in the outcrop, owing to the transgression of the granophyre-sill. The actual passage of the Bryn Brith Beds under the granophyre is not visible, owing to some minor but complicated faulting, due to the fact that the strike suddenly changes from approximately north-east and south-west to more nearly east-and-west. The uppermost agglomerate-like beds reappear, however, on the south side of the granophyre near the farm of Glasdir Mawr, and from this point to Gelli-llwyd they give rise to a marked escarpment overlooking the hollow occupied by the sill. Another sudden change in the strike then brings the beds on to the steep dip-slope that runs down to Llyn Gwernan, and so eventually under the alluvium of the fault-valley.

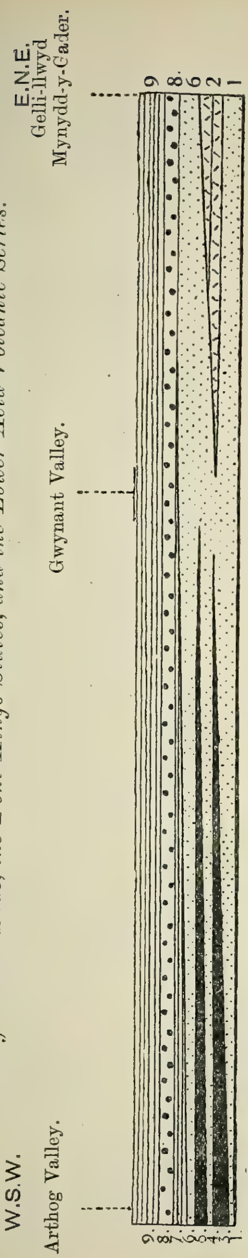
As was the case in the Lower Acid Series, so likewise in the Bryn Brith Beds certain differences are visible between the developments west and east of the Gwynant respectively, differences that assert themselves both in the actual composition of the strata and in their relations to the rock-groups above and below.

On Gelli-llwyd, for example, there is a more gradual upward transition into Crogenen Slates than on Bryn Brith, where the change is quite sudden. More important is the fact that on Gelli-llwyd the Bryn Brith Beds rest directly on the ashes of the Lower Acid Series, without the intervention of any slates comparable with the Moelyn Slates. In fact, there appears to be at this locality a complete transition between the topmost ashes of the volcanic series and the lowest ashy beds of the Bryn Brith Group, and hence it is difficult to fix the exact point at which the dividing-line should be drawn. The Bryn Brith Beds then on the east rest directly upon and pass down into, clastic volcanic rocks, from which, on the west, they are separated by a considerable thickness of slate (fig. 2). The formation was evidently deposited during a period when a large volcanic pile was undergoing rapid erosion. It

is to this that the formation owes its transgressive relations to the underlying beds, and also its peculiar lithological features. The sea was evidently subject to the influence of strong currents which rolled up the ashy mud of the sea-floor into balls that were carried along, and dropped elsewhere among sandy and ashy deposits. Somewhat similar structures may be found in certain beds of the Carboniferous Limestone, in which deposition has been simultaneous with contemporaneous erosion elsewhere. Conglomerates which consist of pebbles of marl in a matrix of sandstone are known both in the Old Red Sandstone and in the Trias.

It is further evident that Gelli-llwyd is situated on what was the western edge of the volcanic pile. This is indicated by the fact that it is precisely at the point where the rhyolitic rocks increase in thickness rather suddenly, that the transgression of the Bryn Brith Beds takes place. Where was the eastern limit of the volcanic pile cannot be ascertained until the examination at present in progress by one of us (A. K. W.), of the country east and north-east of Dolgelley has been completed in more detail.

Fig. 2.—*Diagrammatic section illustrating the original relationship existing between the Bryn Brith Beds, the Pont Kings Slates, and the Lower Acid Volcanic Series.*



9 = Crogenen Slates. 8 = Bryn Brith Beds. 7 = Moelyn Slates. 5 & 3 = Pont Kings Slates.
1 & 4 = Ashes of the Lower Acid Series. 2 = Rhyolites of the same. 6 = 'China-stone' Ashes.

(iii) The Crogenen Slates.—The Crogenen Slates form the best-defined of all the slate-bands among the lower part of the Ordovician sequence. They succeed the coarser strata of the Bryn Brith Beds rather abruptly, especially so in the western part of the area.

The slates are rather pyritous, and are dark blue to almost black, according to the degree of cleavage, the less cleaved material showing, as usual, the darker colour. They weather first rusty, and finally bleach to a pale grey. Ashy material is frequently present, distributed either sporadically, or in little bands from a fraction of an inch up to several inches thick. Besides the thin bands we find also thicker ash-bands, definite enough to be traced over considerable distances. One such massive, fine-grained, rhyolitic or china-stone ash can be picked up at intervals from the Arthog Valley to Penrhyn-gwyn, and is especially noticeable on either side of Llynau Crogenen.

The thickness of the slates is about 300 feet, but is difficult to estimate exactly. Despite the fact that they produce a marked hollow, exposures are plentiful all along the outcrop. They are the most uniformly fossiliferous of the Ordovician slate-bands, and as such proved very useful in elucidating the structure. The characteristic fossils were obtained at numerous localities, as indicated on the map (Pl. XX); the most fossiliferous locality is the small quarry on the west side of Llyn Crogenen, near its outlet. Here graptolites are extremely abundant, and include *Didymograptus bifidus*, *D. stabilis*, *D. artus*, and *D. nanus*. Trilobites are rare in these beds, just as elsewhere in North Wales. A single example, probably *Æglina caliginosa*, was obtained at the quarry mentioned above. Another, *Trinucleus* sp., was obtained, in association with *Climacograptus* and *Didymograptus bifidus*, from slates near Tyddyn Farm, east of the Gwynant.

(iv) The Cefn Hir Ashes.—The Crogenen Slates are succeeded abruptly by a thick ash-group, consisting, in its lower portion, mainly of massive, fine-grained, 'andesitic' ashes, and in its upper portion of coarser ashes and massive agglomeratic beds, composed of pebbles of rhyolitic to andesitic material set in a fairly-coarse ashy matrix. The andesitic ashes include a little above their base a band of slate of normal *Bifidus* type. At the top of the group the massive ashes are succeeded by a small thickness of slaty ashes and slates which, on Cader Idris, have yielded a rather starved-looking *Didymograptus bifidus*. The whole group is about 300 feet thick.

The lowest members of the group are hard fine-grained ashes, which for the most part represent the finest dust of rather acid 'andesites,' or more strictly, of keratophyres, sometimes mixed with argillaceous material now more or less silicified. Some bands are uniformly fine-grained, while others are coarser, and contain numerous small broken felspars and small pellets of ashy material not very different from the matrix in which they are embedded. Although mainly fine-grained the beds are exceedingly massive, and, being well jointed, they break down into great rectangular blocks. These lowest ashes are 40 to 50 feet thick.

Above, comes a band of dark slate, rather hard and flaggy, but otherwise similar to the main mass of *Bifidus* Slates. The slates are associated in their upper portion with massive 'andesitic' ashes, composed of interbanded dark-blue and grey material with a very regular lamination. The thickness of the slate-band, with its associated laminated ashes, is about 20 feet.

It is a curious coincidence that there should be a slate-band intercalated in the Cefn Hir Ashes and occupying the same relative position with respect to the ash-group, as the slate-band in the Bryn Brith Beds does to the latter beds. Such a coincidence might make it appear that the Cefn Hir Ashes are merely a faulted repetition of the Bryn Brith Beds, were it not that a detailed comparison shows that the two groups of ashy beds are lithologically quite distinct.

The slate-band is followed by the main mass of the ash-group, the ashes of which are very variable in character. The fine-grained andesitic or keratophyric type reappears, sometimes passing into ash of the 'china-stone' type, blue-hearted and white weathering, and with the usual splintery jointing. These fine-grained types are interbanded with, or overlain by, massive bands of coarser material, often well laminated. Among these latter beds, in the centre and upper part of the main ash-group, massive agglomeratic beds appear. These consist of pebbles, lapilli, and small chips of fine-grained, white-weathering, porcellanous material, probably an andesitic or rhyolitic ash, set in a more or less abundant dark-grey matrix. In some beds the pebbles are of large and variable size, up to 1 foot in diameter, and sporadically distributed; in others the pebbles are of more uniform size, averaging about three-quarters of an inch in diameter, and making up the greater part of the stratum, thus giving rise to a rubbly-looking rock that weathers quite white, like a normal rhyolitic rock.

The ash-group is terminated upwards by a zone of slaty ashes and ashy slates. One of the lower of these slate-bands is full of curious pebbles, half an inch to an inch in diameter, of a porcellanous ash, giving rise to a very characteristic band which, although quite thin, can be picked up at intervals over a wide stretch of country. The thickness of these uppermost slaty ashes is rather variable at different localities, varying from 40 to 100 feet. The differences are probably due to a certain amount of strike-faulting, which might naturally be expected to select a thin zone that forms a plane of weakness between the two sets of hard massive beds, the main Cefn Hir Ashes below, and the Lower Basic Series above.

The Cefn Hir Ashes, following on the soft Crogenen Slates, determine the position of a craggy ridge beyond which comes a small hollow determined by the outcrop of the thin slaty zone that occurs at the top of the ash-group. Where the massive ashes have been somewhat hardened by the granophyre, the feature due to them becomes especially prominent, resulting in the fine precipitous scarp and jagged ridge of Pared-y-Cefn Hir, 1200 feet, which presents so striking an appearance, as viewed from Llynau Crogenen (Pl. XVII). The scenery on the opposite, or south side, of the lake presents a remarkable contrast: for, on this side, the great craggy feature has disappeared, or, more strictly speaking, has shrunk to a series of tumps. The sudden diminution of the feature is due to the fact that on the south side of the lake the granophyre has transgressed on to beds above the ashes, which latter have consequently not suffered contact-alteration. Owing to the presence of the intrusion on the north side of the lake, the full sequence of the ashes is not seen on that side. The full sequence is present south of the lake where, however, owing to the above-mentioned diminution of the features, exposures are not so good as on the northern shore.

The Cefn Hir Ashes are only seen in the west of the area covered by the map (Pl. XX). Followed eastwards along the ridge of Pared-y-Cefn Hir, they gradually disappear against the granophyre-

sill. On the south side of the sill the agglomeratic beds reappear on Mynydd Caer-go, only to be cut out by a normal fault near Cefn Owen, so that their outcrop does not reach the Gwernan Fault. South of this fault, however, and outside the area at present considered, the ashes have been followed along the flank of Cader Idris as far as the Aran Valley. Their lithology is so characteristic that they furnish a most useful datum-line in mapping the country.

Coming immediately underneath a thick volcanic series—the Lower Basic Series—it may appear that the Cefn Hir Ashes should be grouped with this volcanic series, especially since some of the ash-beds in the Cefn Hir Ashes are similar to ash-beds intercalated in the Lower Basic Series. But there is a general predominance of somewhat acidic material in the Cefn Hir Ashes, as opposed to the thoroughly basic character of the overlying lavas. Moreover, there is the distinct slaty zone between the Cefn Hir Ashes and the lavas, although this has, perhaps, no great significance, since slate-bands also occur intercalated within the Lower Basic Series. But, taking all the facts into consideration, we have deemed it advisable to separate the ashes as a distinct formation, particularly since they have proved so useful in mapping the country.

(4) The Lower Basic Series.

The Lower Basic Series consists of a great thickness of basic lavas, with various ashy and slaty intercalations, and with numerous intrusions of basic material. Many of the lavas are typical spilites. As the series is more completely developed on the northern slopes of Cader Idris, it is proposed to defer a more detailed account until the geology of the Cader-Idris range is described. It may be mentioned, however, that the pillow-lavas and associated ashes may be seen at various points between Llynau Crogenen and Hafotty Fach, and also on the dip-slope of Mynydd Caer-go.

The exact age-limits of this basic volcanic series have not yet been definitely settled. As already stated, the slaty beds (of the Cefn Hir Ashes) immediately underlying it contain *Didymograptus bifidus*. On Cader Idris a band of slate that appears to belong to the volcanic series has yielded graptolites which, although the exact species are unfortunately indeterminable, appear to be of Llandeilo age. The strata that immediately overlie the lavas probably belong to a high horizon in the Llandeilo.

III. The Intrusive Rocks.

(A) The Diabases.

(*a*) Field-relations.—As will be seen from a glance at the map (Pl. XX), sills and laccolitic masses of diabase are extremely abundant throughout the district. It is also apparent that the intrusions are not limited to any particular stratigraphical horizon, but that they occur throughout the whole range of formations in the area mapped, with a maximum development at the horizon of

the Lower Acid Series. Moreover, the intrusions grow larger, when followed from west to east, roughly in proportion as the Lower Acid Series itself thickens when traced in the same direction.

The intrusions behave generally as sills, which (even when quite thin) often maintain themselves at the same stratigraphical horizons over long distances. Occasionally, however, the intrusions gradually transgress for a time on to a lower horizon, but eventually resume their former position. This is illustrated by the Gelli-llwyd Cae-Einion sill, and by the intrusions near Arthog. In such cases it is sometimes found that the sedimentary rocks are affected by shallow north-and-south anticlinal folds, which have also affected the intrusive rocks, although not to the same extent as the stratified rocks. Further reference will be made to this point (see p. 307).

But, although the intrusions generally behave as sills, there is at times a strong tendency for their lower boundaries to transgress northwards on to lower stratigraphical levels. As a result, highly-inclined sedimentary rocks are often concealed from view by a more or less horizontal cake of diabase, and it frequently appears, therefore, as if the diabases are more numerous, or have a wider spread, on the higher ground. Instances of this peculiar relation between intrusive and stratified rocks have already been described by Mr. Lake & Prof. Reynolds in the case of the diabases near Dolgelley,[1] and in considerable detail in the case of the great mass of Mynydd-y-Gader,[2] the largest diabase intrusion in the district, which probably represents merely a faulted repetition of the occurrences nearer Dolgelley. Similar relations hold for the westward continuations of the Dolgelley sills; but, in view of the accounts quoted above, there is no need to enter here into detail regarding particular cases.

Petrologically, various types may be distinguished by their texture and quartz-content; but we have not, so far, determined any direct relationship between these types and the stratigraphical levels at which they occur. It seems probable, therefore, that all the diabases belong to a single phase of igneous activity, and that all are approximately of one and the same age. The actual date of the intrusions will be discussed later (p. 304).

(*b*) Petrology.—All the varieties that may be distinguished by texture and mineral composition belong to types which have a wide distribution among the Ordovician rocks of Wales. Since numerous examples of such rocks have been described from other localities, no good purpose would be served by entering upon a detailed description at this point. Accordingly, only the main features need be noted.

All the true diabases are of simple mineralogical composition, the main differences being those of texture. Neither olivine nor rhombic pyroxene has been discovered, the essential minerals being plagioclase and augite with their respective alteration-products.

[1] Q. J. G. S. vol. lii (1896) p. 517.
[2] *Ibid.* vol. lxviii (1912) p. 349.

Many of the coarser-textured examples are beautifully ophitic in their central portions, notably the Cae-Einion sill at the point where it crosses the Gwynant, also the sill alongside the main road west of Arthog. In other cases, or even in an intrusion that is normally ophitic, it is not uncommon to find the augite tending to form euhedral crystals. This takes place even in rocks so coarse as to be gabbroid, as, for example, in parts of the Gelli-llwyd intrusion; such rapid changes in texture show how evenly balanced were the conditions which determined the idiomorphism or otherwise of the augite.

The pyroxene is always a pale variety, sometimes green, sometimes pinkish brown [C 248].[1] The felspar occurs in the usual idiomorphic tabular crystals, appearing as large plates or laths according to the direction of section. It is near albite in composition, and is usually altered to a greater or less extent, being crowded with finely-divided epidote and zoisite. At several localities hand-specimens of the rocks show numerous pale patches measuring up to a centimetre or more in diameter. These patches are almost opaque, except in thinnest sections when they are resolved into an equi-granular mosaic of epidote and zoisite replacing large felspars. Examples of this type occur locally on Gelli-llwyd [C 247 & 250]; also at Bron-y-Gader,[2] where they have been quarried for building-material.

Contact-altered diabases.—The Gelli-llwyd diabase has been cut by the later Crogenen granophyre, and has consequently suffered a certain amount of contact-alteration. This has led to a partial clarification of the felspars and to a complete recrystallization of the dark mineral which, while originally augite, is now represented by pale hornblende crowded with magnetite-grains. The hornblende has penetrated as long fibrous crystals right through the larger felspars, and this recrystallization has obscured the original texture, which was probably subophitic. The changes seem to be so similar to those brought about in other cases of contact-metamorphism of dolerites by granitic rocks that there is no need for detailed descriptions. One curious feature of these contact-altered dolerites, now in the form of albite-hornblende rocks, is their mineralogical similarity to the marginal basic modifications of the granophyre with which they are in contact. The two rocks are only distinguished by the altered dolerite being of coarser grain (see p. 288 for details as to junctions).

The spilite-like diabases.—A set of basic intrusions occurs in the Lower Basic Series, being especially abundant among the lowest beds of the series, and also appearing in beds below, that is in the Cefn-Hir Ashes and occasionally in the Crogenen Slates. Individual intrusions are usually small, with the result that the rocks are usually fine-grained and vesicular. In such cases it is not easy to distinguish them from the pillow-lavas among which they occur. As the intrusions increase in size, they pass over into rocks more comparable with the normal diabases described above. It seems probable that these intrusions are almost contemporaneous with the lavas, and that they simply represent small masses of lava-material, which did not succeed in finding their way to the surface, but consolidated under a shallow cover, so

[1] The numbers in square brackets refer to slides in our 'Cader-Idris' collections.

[2] G. A. J. Cole & A. V. Jennings, Q. J. G. S. vol. xlv (1889) p. 432.

that they show textures intermediate between those of the lavas and the normal diabases.

The mass which forms Tyddyn Camp Hill and is intrusive into the Crogenen Slates seems to belong to this series. It is a fine-grained rock, the texture being but little coarser than that of a typical spilite. Like a spilite, it consists [C 244] of a plexus of minute felspar-laths and fibres often curved and forked, the interspaces being occupied by pale-green chlorite and wisps of hornblende, along with patches of murky interstitial material which represents altered glass. Vesicles infilled with chlorite and epidote are abundant. Felspar-phenocrysts occur sparsely; their outlines are irregular, owing to corrosion. There can be no doubt that the rock has practically the composition of a spilite.

(B) The Granophyres and Related Rocks.

(*a*) Field-relations.—Although intrusions of basic material are so abundant, only two intrusions of thoroughly acid material are known in the whole district round Cader Idris. Each of these is, however, of considerable size, so that the bulk of acid material exceeds the total bulk of the far more numerous basic intrusions. Of the two acid intrusions, one is well known from its forming so prominent a feature in the cliffs of Cader Idris; it has been described by Ramsay [1] and by Prof. G. A. J. Cole & Mr. A. V. Jennings [2] under the terms 'felspar-porphyry' and 'eurite' respectively. The other intrusion—the Crogenen granophyre—has received but passing notice from previous observers.

Actually, we find a whole set of intrusions made up of granophyric rocks which, considered together, show all transitions from thoroughly basic to thoroughly acid rocks. The more basic types approximate to quartz-dolerites in composition, and they pass through types which may be described as relatively basic granophyres, or 'markfieldites,' into normal acid granophyres which have the composition of a microgranite. Acid granophyre is the dominant type as regards bulk, the more basic types merely representing early differentiates from the acid magma. In the field the most basic of these granophyric differentiates are at first sight liable to be confused with the diabases. But a closer inspection shows that they should be linked with the acid granophyres, and that they belong to a set of intrusions distinct from, and of later date than, the true ophitic diabases. We do not preclude the possibility of there being a genetic connexion between the ophitic diabases and the acid granophyres; that some such connexion exists is almost certain. But we wish to emphasize that the basic rocks in question are more closely linked to the acid granophyres than to the ophitic diabases. Within the area mapped granophyric rocks occur in five intrusions, which are all laccolitic or sill-like in form. Four of these are relatively small, and are composed either entirely or in part of more or less basic material. In general, each laccolite or sill is less basic than the one stratigraphically below it; further, within the limits of each mass the rocks at the bottom tend to be

[1] 'Geology of North Wales' Mem. Geol. Surv. vol. iii, 1st ed. (1866) p. 27.
[2] Q. J. G. S. vol. xlv (1889) p. 433.

more basic than those at the top (section, fig. 4, p. 289). The main intrusion of acid material in its turn is stratigraphically above the more basic intrusions. But, in contrast to the others, the larger sill shows no stratiform variation according to density. In its case both lower and upper contacts are composed of thin zones of basic material; the bulk of the mass, however, is uniformly acid in composition, and shows but little variation in the field. Since this intrusion is so much larger than the others, and its rocks are so distinctive in the field, we shall describe it separately under the term 'Crogenen granophyre', and return later to the more basic granophyres.

(1) The Crogenen Acid Granophyre (or Microgranite).

The main outcrop stretches from Llynau Crogenen on the west to Gelli-llwyd on the east, a distance of $3\frac{1}{2}$ miles, with an average width of nearly half a mile. It belongs to a mass which is sill-like in habit, and is accordingly repeated on the south by the Gwernan Fault. The southern outcrop is now separated into two portions: a small eastern one near Penrhyn-gwyn, and a much larger western portion below Tyrau-mawr and extending for three-quarters of a mile beyond the south-western boundary of the map (Pl. XX).

The sill, therefore, spreads approximately along the strike for a distance of over 5 miles. In the direction of dip it can be followed for nearly 2 miles, and how much farther it may extend in that direction it is impossible to say, as a little beyond the southern boundary of the map the steep dip carries it deep underground, so that its further prolongation is everywhere concealed by overlying rocks.

It will be noticed that, in its course from east-north-east to west-south-west, the intrusion gradually cuts across all the sedimentary strata, from the Tremadoc Slates to the Lower Basic Series. The transgression is continued beyond the south-western boundary of our map (Pl. XX) and the intrusion cuts into slates well above the Lower Basic Series. The southward transgression is also brought out by the fact that, whereas on Gelli-llwyd, north of the Gwernan Fault, the sill is in the Lower Acid Series below the Bryn Brith Beds, at Penrhyn-gwyn, on the south side of the repeating fault, the intrusion is above the Bryn Brith Beds and in the Crogenen Slates. The westward transgression is shown by the reappearance of the Penrhyn-gwyn sill at still higher stratigraphical levels on the slopes of Tyrau-mawr.

The sill-like habit of the intrusion can be inferred from the manner in which its outcrops are repeated by the Gwernan Fault, and also from other considerations. Actual rock-exposures of the sill margins are not common, owing to the fact that the granophyre almost invariably occupies lower ground than the invaded rocks whether sedimentary or igneous, and accordingly junctions

are usually obscured by slipped material. Nevertheless, the actual base of the intrusion is visible at various points, especially along the slopes of Pared-y-Cefn Hir, and it is seen to dip in the same direction, and at nearly the same angles as the adjacent stratified beds. The top of the intrusion is not well displayed along the central outcrop; but, where it is repeated, below Tyrau-mawr, the relations are clear enough, and the upper boundary of the intrusion dips with the superincumbent strata. Moreover, the rock almost invariably possesses a columnar jointing, and the columns, wherever found, show a uniform 'dip'; they are, therefore, presumably arranged at right angles to the top and bottom of the intrusion. Now, the direction of the columnar jointing is exactly such as would be expected in a sill dipping approximately with the adjacent sedimentary rocks.

The evidence from the distribution of the outcrops, the nature of the junctions, and the character of the columnar jointing, all combine, therefore, to show that the intrusion is everywhere to be regarded as a sill. This clear proof of the sill-like habit is the more interesting when account is taken of the steady and gradual transgression of the intrusion into higher beds when followed from north-east to south-west.

When we first began work in the district it seemed possible that the appearance of transgression was really due to faulting along the margin of the intrusion. This view gained support from the fact that the margins of the main sill are overlooked in each case by scarps, the one on the south side being particularly prominent. These scarps are formed by the various sedimentary and igneous rocks that are in contact with the granophyre, the scarp itself being almost independent of the kind of rock of which it is composed. This feature is especially striking on Gelli-llwyd, where the well-marked scarp is composed, in different parts of its course, of diabase, of various rhyolitic rocks, and of Bryn Brith Beds. The course of the scarp is quite independent of the run of these various beds which strike, indeed, diagonally across the feature. It seemed possible, therefore, that this scarp was nothing but a fault-feature. Further examination, however, revealed the presence of the peculiar basic rocks characteristic of the granophyre margin, while elsewhere actual chilled margins of granophyre were discovered. Obviously, therefore, the junctions of the granophyre with the sedimentary rocks were normal and not faulted, and it follows that the appearance of transgression displayed on the map (Pl. XX) is due to an actual transgression, and not to faulting.

The gradual transgression and the sill-like habit of the intrusion were noticed by Ramsay ('Geology of North Wales' Mem. Geol. Surv. vol. iii, 1st ed. 1866, p. 25), who remarked that the intrusion took place

'. . . . . before those later disturbances occurred that threw both stratified and igneous rocks into their present curved and inclined position. . . . .'

This statement is completely justified by further evidence that has been obtained during the examination of the district.

The south-westward transgression on to higher beds at once suggests that the sill had its origin at some point away to the north-east, and that the flow took place from the north-east where the rocks have since been removed by denudation, towards the south-west, in which direction the sill now dives deep underground. Further evidence in support of this view may be adduced from the distribution of the minor granophyric intrusions.

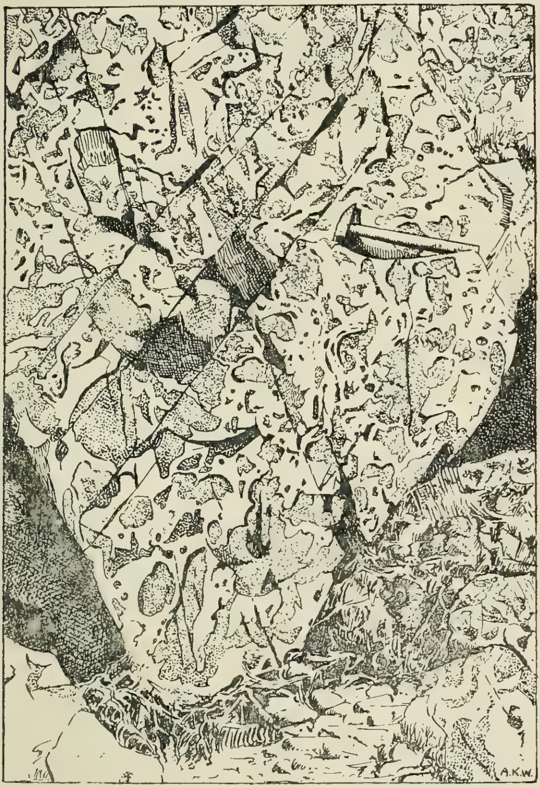
The actual point of origin of the great sill remains undetermined. The north-eastern extremity lies buried beneath the alluvium of an old, matured river-valley. There is accordingly an area having a width of up to a third of a mile where exposures cease, and it is quite possible that the root of the sill is situated under this alluvium in the neighbourhood of Tal-y-waen. No other intrusion of acid rock has been found between this point and the boundary of the estuary, a mile to the north. Then comes another stretch of alluvium half a mile to a mile wide, that might conceivably conceal the duct through which the magma rose. North of the estuary there is, so far as we are aware, no intrusion of granophyre (or microgranite) comparable to that of the Crogenen granophyre; no such rock is present in the area examined by Dr. A. R. Andrew.[1] It is probable, therefore, that the duct is situated under the sill itself, or under the alluvium that borders it in the neighbourhood of Tal-y-waen. This supposition is supported by the fact that the minor granophyric intrusions are concentrated near this locality.

Basic marginal modifications of the Crogenen granophyre.—Along both upper and lower margins the Crogenen granophyre passes into darker basic rocks, which in their colour, mode of weathering, etc. closely simulate a diabase. The marginal zones are each from 50 to 100 feet thick, and within this thickness there is usually a perfect transition from thoroughly acid to thoroughly basic rock. These marginal rocks evidently represent a differentiation-product of the main granophyre, and the perfect transition between the two types and the general absence of any pronounced brecciation suggest that the differentiation was accomplished in place. This view is further strengthened by the uniform character which the marginal zones, although so thin, maintain over many miles. Such uniformity of comparatively thin zones over great distances could not be expected if the basic rocks represented an earlier and deep-seated differentiated product. Exceptionally, intrusion-breccias do occur, a good example being found at the western end of Pared-y-Cefn Hir. There the earlier consolidated marginal basic product has been fractured, as the result of some local movement, and the fractures injected with

[1] 'The Geology of the Dolgelley Gold-Belt' Geol. Mag. 1910, p. 159.

normal acid granophyre (fig. 3). The origin of the intrusion-breccias and the local movements is to be looked for in the existence precisely at this point of thin strips and lenticles of ash enclosed within the lower part of the intrusive mass. The strips are hardly big enough to be shown on the map (Pl. XX). Neither were they big enough to interfere with the process of differentiation in place, so that the basic marginal rocks occur in their usual

Fig. 3.—*Intrusion-breccia, Pared-y-Cefn Hir.*



A. K. W. del.

[The basic marginal rock is dotted, the granophyre is left unshaded.]

position. But, as the magma cooled and contracted, the lenticles appear to have undergone a settling-down, the result of which is apparent in the reversed dip of some of the smaller masses. The settlement of solid material opened new channels enabling the still molten acid material of the intrusion to invade the already consolidated differentiation-product at the margin. For the greater

part the invaded basic material was still too hot to have exerted any chilling effect upon the invading granophyre.

Since these marginal basic modifications of the granophyre are often found in contact with diabases (see p. 282), it might be thought that they represent hybrids formed owing to the absorption of diabase by granophyre, such as have been recorded by observers in other districts. The presence of the basic modification at localities removed from any actual diabase-intrusion would then be easily explicable either on the theory (i), that the original diabase had been modified in its entirety, or (ii), that the hybrid material, originally formed at some diabase-contact, had been subsequently swept along by the westward movement of the acid magma. This was our own impression when these rocks were first observed. A closer inspection both of the field-junctions and of thin sections showed, however, that this hypothesis could not hold. The junctions of the basic material with the diabases are always quite sharp. This can, as a rule, be readily recognized, owing to the marked differences in texture between the true diabases and the marginal basic rocks. Moreover, the marginal rocks are sometimes seen to be distinctly chilled against the normal diabase. Further, there is never any sign of brecciation (intrusion-brecciation) of the coarse diabases by the granophyric magma. Thus the origin of the marginal rocks cannot be connected with the diabase intrusions of the district.

It is noteworthy that the most basic of these marginal rocks resulting from differentiation in place closely resemble the basic rocks of the Waen-Fechan intrusion, which represents a deep-seated differentiation-product of the granophyre magma (pp. 290 & 297). Similar rocks which originated in a similar manner, are found associated with part of the margin of the Buttermere and Ennerdale granophyre, and also as small separate intrusions near the main granophyre,[1] exactly comparable with the Waen-Fechan and Tyn-y-llwyn intrusions which will be described below. Similarly, basic rocks occur again along the margin of the Carrock-Fell granophyre.[2]

(2) The Minor Granophyric Intrusions.

In addition to the main Crogenen sill just described, there are some four (or five) smaller intrusions of granophyric rocks. They consist for the greater part of rocks that are consanguineous with, but more basic than, those of the main sill. These minor intrusions all occur north or north-east of the main mass, and not at any other points along its course, thus giving additional support to the hypothesis of a north-easterly point of origin for all the granophyric rocks (p. 286). They show, moreover, that there was some tendency for the intrusions as a whole to assume a form comparable with that of a cedar-tree laccolite. In this respect the

[1] R. H. Rastall, Q. J. G. S. vol. lxii (1906) p. 268.

[2] A. Harker, *ibid.* vol. li (1895) p. 134.

Crogenen granophyre closely resembles the Buttermere and Ennerdale granophyre.[1] The Welsh and the Lake-District intrusions present other points of similarity, for both show similar marginal rocks formed under similar conditions, both are intrusive into Lower Ordovician strata approximately along the junctions of a slate series with a volcanic series, and, as will be shown later (p. 304), the intrusions in both districts are probably of the same age.

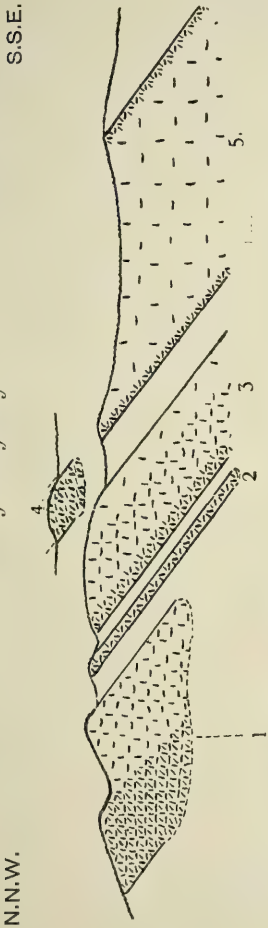


Fig. 4.—*Diagrammatic section through the minor intrusions of the Arthog–Dolgelley area.*

1 = Craig-y-Castell intrusion. 3 = Larger Tyn-y-llwyn intrusion.
2 = Smaller Tyn-y-llwyn intrusion. 4 = Waen-Fechan intrusion. 5 = Crogenen sill.

[Close stipple indicates basic granophyric rocks, medium stipple markfieldites, wide stipple eurites. Junctions are indicated diagrammatically; in the field they are not so sharply defined.]

The minor intrusions are separated one from the other and from the main sill by small thicknesses of Dolgelley or Tremadoc Beds; unlike the main sill, they never intrude into Ordovician rocks. They may conveniently be styled the Craig-y-Castell, the smaller and the larger Tyn-y-llwyn, and the Waen-Fechan intrusions respectively. Detailed references to their modes of occurrence are unnecessary, since most of such information can be obtained from the map (Pl. XX).

As regards the composition of the rocks: (i) The Craig-y-Castell intrusion is in its lower half composed of a basic granophyric rock closely comparable with many quartz-dolerites. The upper half of the intrusion is composed of a coarse-grained markedly granophyric rock less basic than that in the lower half, but distinctly more basic than the typical Crogenen rock. It appears, in fact, to be similar to, but perhaps somewhat more basic than, the well-known granophyres of Markfield and Groby in Charnwood Forest; accordingly, the term markfieldite may fittingly be applied to it (see below, p. 300).

[1] R. H. Rastall, Q. J. G. S. vol. lxii (1906) p. 253.

(ii) The smaller Tyn-y-llwyn intrusion is composed, as regards its lower portion, of a fine-grained truly basic rock; upwards it becomes coarser in grain and somewhat less basic in composition—Tyn-y-llwyn type—but still remains more basic than the markfieldite type. The coarser and less basic rock contains numerous xenoliths of the fine-grained basic type.

(iii) The larger Tyn-y-llwyn intrusion contains a number of types showing every transition from basic to acid rocks. The rocks along its lower margin were evidently formed almost simultaneously with those in the smaller Tyn-y-llwyn intrusion below, the same types being present in both intrusions. Upwards, however, the highly-basic granophyres and rocks of Tyn-y-llwyn type gradually become less basic, and pass into the coarse-grained markfieldite type. This in turn passes into a finer-grained and truly acid rock which cannot be distinguished from the typical Crogenen granophyre. The coarse markfieldite type and the acid Crogenen or eurite type are connected by a transitional zone in which the rock, while it cannot be distinguished from the eurite type along surfaces showing a fresh fracture, yet weathers grey instead of white or vermilion. The uppermost zone of this intrusion shows in one locality a return to the somewhat basic markfieldite type, chilled at the actual contact.

(iv) The Waen-Fechan intrusion, though stratigraphically higher than the other minor intrusions, yet consists of a thoroughly basic rock (Waen-Fechan type) comparable with, but even more basic than, the lower half of the Craig-y-Castell mass.

(*b*) Petrology of the granophyric rocks. (1) The Crogenen granophyre. (*a*) The normal acid rocks.—Macroscopic characters: The granophyre is exceedingly uniform over the whole extent of its outcrop as regards its appearance in hand-specimens, always excepting the marginal modifications that will be described later (p. 295). The fresh rock is grey-blue, and presents a fine-grained 'felspathic' appearance, no distinct minerals being identifiable, apart from small and scattered felspar-phenocrysts. These are lath-shaped in section, and show a vitreous lustre. They persist even into the basic modifications of the granophyre, and form a ready means of distinguishing such modifications from the true diabases.

The normal rock weathers white, while joint-surfaces are often blotched irregularly with yellow or occasionally with vermilion. Just beneath the weathered crust little rounded white spots may frequently be observed; these spots represent micrographic quartz-felspar aggregates, but they are not visible in the fresh specimen. The rock breaks with a smooth fracture, yielding chips with knife-like edges comparable to those derived from rhyolites. The gravelly sub-soil material derived from the granophyre shows, however, a more reddish tinge than the corresponding material from a rhyolite.

Microscopic characters.—The uniform character observed in hand-specimens is seen again under the microscope, so far as regards the mineralogical, and presumably therefore also the chemical composition. The granophyre is everywhere a distinctly acid rock, consisting almost entirely of quartz and alkali-felspars. Dark minerals are sometimes almost completely absent, and are always quite subordinate in amount, being usually represented only by chlorite. In the marginal modifications, however, biotite and hornblende make their appearance.

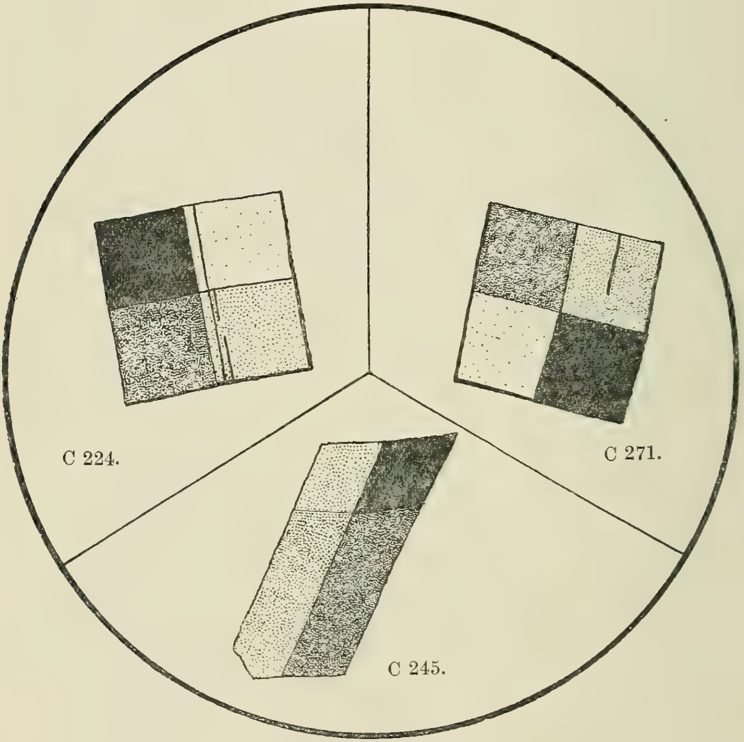
The rock presents these same features throughout the length and breadth of the sill, the only changes being due to slight variations in the texture. These variations are not, however, on such a scale as to be appreciable in the field; they are simply variations in the degree to which micrographic intergrowths are developed, and they may be observed within the limits of a single slide.

With regard to the characters of the minerals present, in examples from the typical rocks the only porphyritic or microporphyritic minerals are the felspars. Even they are not abundant, but each slide usually contains some examples which are generally clustered together in groups of two or three highly-idiomorphic individuals, sometimes partly surrounded by irregular plates of chlorite. Both orthoclase and plagioclase are represented, the latter with albite and pericline and less common types of twinning. One type, though somewhat uncommon, appears to be characteristic of the rock and its modifications. Cross-sections, perfectly square in shape, show diametral twin planes which divide the section into four equal squares; each of these differs in interference from the others (fig. 5, p. 292). Extinction-angles and refractive indices correspond to an almost pure albite. In one case inclusions of quartz-granules were observed. The orthoclase-crystals are about the same size as the plagioclases, but they are not always truly idiomorphic towards the ground-mass, showing that part of their growth took place at quite a late stage. The late growth is further shown by the manner in which chlorite has been pushed outwards by the growing felspars. Both felspars are only moderately dusty-looking in fresh specimens, and they do not possess the spongy structure characteristic of the secondary albite in certain diabases; they may become filled with sericite, albite, and chlorite, but only as the result of weathering. The microporphyritic felspars resemble the felspar of the ground-mass in all respects, except in size.

The ground-mass consists of quartz, felspar, and chlorites. In normal specimens the quartz occurs as rather large grains which interlock quite irregularly, and enclose small partly-idiomorphic felspars. Whereas the quartz may act as a single crystal over relatively large areas, the felspars, as a rule, behave quite independently of each other. Thus the quartz acts as the host, and the texture is micropoikilitic rather than micrographic. Such rocks might perhaps be better described as microgranites rather than as granophyres.

The felspars of the ground-mass include both plagioclase and orthoclase. The former is distinctly idiomorphic, whereas the latter is irregular in outline; sometimes a partly-idiomorphic plagioclase is surrounded by allotriomorphic orthoclase. The orthoclase occasionally presents the patchy or streaky appearance indicative of a soda-orthoclase. All gradations between perfectly untwinned crystals and markedly patchy ones may be observed. There is evidently a fair amount of soda in the molecule.

Fig. 5.—*Sections of felspar-twins, Crogenen granophyre, crossed nicols.* × 50.



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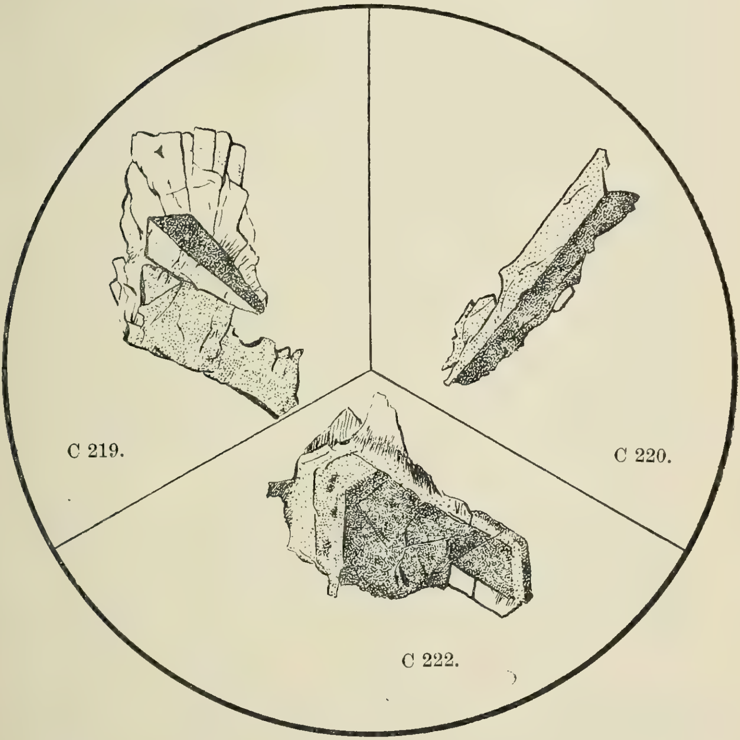
Chlorite occurs rather abundantly as specks, granules, threads, and larger aggregates, especially round the felspars, or separating the felspars from quartz, and even enclosed in quartz. Pleochroism is very marked in the chlorite of the larger patches, whereas the chlorite of the smaller granules and threads is pale with hardly observable pleochroism, though it may sometimes be birefringent. It is not easy to see from what original mineral this chlorite has

been derived; probably, from analogy with somewhat more basic examples of the granophyre, the original mineral was biotite.

Among accessory minerals apatite in very small needles is fairly frequent, also epidote in small granules, occasionally aggregated in little clusters associated with zircons larger than those usually seen in such rocks. Allanite is relatively not infrequent, partly in prismatic forms, and partly granular, entering into a mosaic with quartz and surrounded by obscure secondary products (fig. 6). In

Fig. 6.—*Sections of allanite, Crogenen granophyre, plane-polarized light.* × 50.



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one case [C 219] prisms of zoisite were observed radiating from an allanite-crystal. The idiomorphic allanites are, as a rule, strongly zoned and often twinned. Pleochroism ranges from a very pale brown to a rich chestnut-brown.

As regards the texture observed under the microscope, it has already been mentioned that this is somewhat variable, and may, as almost invariably in granophyres, alter within narrow limits, according to the relative perfection in which graphic intergrowths

are developed. The most widely distributed type would, considered by itself, be best described as a microgranite having a tendency to graphic structure (Pl. XVIII, figs. 1 & 2). Other specimens are, however, typical granophyres with very beautiful and delicate growths of micropegmatite, the exact arrangement of which changes, as usual, with the degree of coarseness, becoming almost centric in the fine-grained types, and so giving a patchy pseudo-spherulitic appearance when viewed under the microscope. Graphic structures are usually best developed in specimens of finer grain, whereas the micrograinitic type is to be found in specimens of rather coarser grain, though some exceptions to this rule do occur (Pl. XVIII, fig. 4). The most markedly granophyric rocks are found in comparatively narrow zones towards both the upper and the lower margins of the sill, though not actually on the margins themselves (Pl. XVIII, fig. 3): for, as the outermost zones are reached, the rocks become distinctly basic, and all traces of micrographic structure disappear (Pl. XIX, fig. 3). Thus in part, at any rate, the development or otherwise of the micrographic structure depends upon differences in chemical composition, which itself is influenced by the position of the rock in the sill.

A further cause of these small-scale variations in the relative development of graphic structures, according to the chemical composition of the rock, is to be found in the gradual destruction of basic patches which represent cognate xenoliths derived from the basic marginal modifications. Such patches of more basic material persist for a long time and for long distances into the sill. The distinction between patches and ground-mass naturally becomes less marked towards the interior, until eventually mere suggestions only of patchiness remain, showing slight variations in the character of the quartz-felspar intergrowth.

Chemical composition.—The Crogenen granophyre has not been analysed; but the rock may be expected to compare closely with the petrologically similar rock on Cader Idris, of which an analysis was recorded by Prof. G. A. J. Cole & Mr. A. V. Jennings, and is quoted below along with the results given by other similar rocks of North Wales and the Lake District.

	I.	II.	III.	IV.	V.
SiO_2	72·79	75·02		71·60	80·12
Al_2O_3	13·77	12·88		13·60	10·68
Fe_2O_3	3·32	2·89		2·40	0·06
FeO	—	—		—	0·49
MnO	trace	—		—	0·05
MgO	0·62	0·32		0·21	0·63
CaO	1·94	1·17		2·30	1·01
Na_2O	4·12	3·28	5·89	5·55	3·44
K_2O	2·99	5·03	3·56	3·53	1·42
Loss on ignition	1·08	0·60		0·70	1·08
Other constituents	—	—		—	1·42
	100·63	101·19		99·89	100·40
	T. H. Holland.	L. W. Fulcher.		G. Barrow.	H. F. Harwood.

I. Granophyre, 'eurite'; Llyn-y-Gader, Cader Idris. G. A. J. Cole & A. V. Jennings, Q. J. G. S. vol. xlv (1889) p. 435.

II. Granophyre, 'granite'; Tan-y-grisiau, Ffestiniog district. A. V. Jennings & G. J. Williams, Q. J. G. S. vol. xlvii (1891) p. 381.

III. Granophyre; Trevor, Yr Eifl (Carnarvonshire). 'Summary of Progress for 1918' Mem. Geol. Surv. 1919, p. 8.

IV. Granophyre; 100 yards east of summit, Carrock Fell, Lake District. A. Harker, Q. J. G. S. vol. li (1895) p. 129.

V. Granophyre; Brandy Gill, Carrock Fell. A. Holmes, Geol. Mag. 1917, p. 406.

The resemblance between these rocks is very close. No. V is exceptional as regards its silica-percentage, but in this case the sample was especially chosen as being a siliceous rock.[1] Soda is in excess over potash in all cases, with the exception of the Tan-y-grisiau rock, and calculations show from 50 to 60 per cent. of plagioclase which varies between Ab 6·5 An I and Ab 7·5 An I.

(β) Marginal modifications of the Crogenen granophyre.—The most basic of the marginal rocks are dark, and resemble at first sight a fine-grained diabase. Like numerous basic rocks they may show distinct traces of banding, and, apart from the banding, there may be a patchiness due to an irregular intermixture of acid and basic material. They weather in most respects like the diabases, but the presence of scattered microporphyritic felspars exactly resembling those in the normal granophyre betrays their true nature (see Pl. XIX, fig. 3), as does also their frequent patchy character (Pl. XIX, fig. 4), which is not seen in the true diabases of the district.

Under the microscope, the most basic types are seen to possess a rather granular texture, distinctly coarser than that of the normal granophyre (Pl. XIX, figs. 2 & 3). They consist [type 2,[2] C 211] essentially of hypidiomorphic felspars and very abundant dark minerals, which include principally a ragged pale-green hornblende and granular magnetite. Granular sphene and acicular apatite are both extremely plentiful as accessories. In such cases quartz may be completely wanting.

The felspar in these rocks, as in the normal granophyres, includes both plagioclase and orthoclase. The latter crystals are quite allotriomorphic, and usually destitute of any kind of twinning. Carlsbad twinning may, however, be seen in some cases; also the characteristic streaky polysynthetic twinning of anorthoclase occasionally makes its appearance, affecting either the whole of a crystal or a part only. Again, therefore, the non-plagioclastic felspar must contain a considerable amount of soda. The plagioclase felspars tend to be more idiomorphic than the orthoclase, but not to so marked an extent as in the granophyre proper. Extinction angles and refractive indices show the felspar to be albite, hence the differentiation of the magma has not affected the composition of the felspars. Both varieties of felspar are in fresh

[1] A. Holmes, Geol. Mag. 1917, p. 403.

[2] The types 1, 2, & 3 are taken in order from the exterior inwards.

samples water-clear, except for fairly numerous primary inclusions of apatite, chlorite (after hornblende), and sphene.

The dark minerals, hornblende and magnetite, need but little mention; the distinctive feature is their great abundance, as they make up nearly a third of the bulk of the rock. The hornblende is mainly pale actinolite of rather acicular habit, and is crowded with magnetite-grains. The acicular character of the dark minerals in marginal modifications of granophyres has been noted by Dr. A. Harker[1] and by Mr. R. H. Rastall[2] in the Carrock-Fell and Buttermere intrusions respectively.

This type (2) may be followed right up to the margin of the country-rock, whatever that may be—diabase, rhyolitic ash, etc. Along the actual margins the marginal basic rocks are distinctly chilled over a thickness of 3 to 10 feet. The chilled rocks [type 1, C 209 & C 304] resemble those described in the preceding paragraph, but are naturally of finer grain; and those felspars that were idiomorphic tend to lose their idiomorphism, partly owing to the way in which they interlock irregularly one with the other, and partly owing to the distribution of the abundant dark minerals. In the case of plagioclase, however, indications of the characteristic shape may still be seen, whereas the orthoclase is entirely allotriomorphic.

Returning to the unchilled basic rocks and following them towards the granophyre, we notice various changes. The plagioclase becomes more idiomorphic away from the chilled zone, and at the same time it builds larger crystals than in the normal granophyre. Quartz soon makes its appearance, first as tiny interstitial patches, then as distinct blebs [C 216]. The appearance of the blebs is then followed by the incoming of first small, and then larger, amounts of extremely fine-grained micropegmatite [type 3, C 217] which gradually increases in coarseness as the rocks become more acid. In these slightly less basic rocks an intensely-pleochroic hornblende (yellow to deep blue-green) takes the place of the pale actinolitic variety found in the most basic of the marginal rocks. Simultaneously with the incoming of quartz and its gradual increase, an intensely-pleochroic biotite also appears in criss-cross wisps which increase in amount at the expense of hornblende. These somewhat less basic marginal rocks also contain allanite, as in the normal granophyre [C 220, fig. 6, p. 293 & Pl. XIX, fig. 2].

As the result of movement during consolidation a certain amount of admixture of previously-differentiated materials has taken place. Thus the most basic type (2) may contain xenoliths of chilled material, type 1 (see Pl. XIX, fig. 4), while the more acid and granophyric type (3) contains xenoliths of both the preceding types (1 & 2). In such cases, acidic and basic materials were brought into unnatural juxtaposition, resulting in the partial or

[1] Q. J. G. S. vol. li (1895) p. 127.
[2] *Ibid.* vol. lxii (1906) p. 265.

complete resorption of the basic material. The finer-grained xenoliths (type 1) usually retained definite outlines; whereas the coarser-grained xenoliths (type 2) were more readily corroded by acid material, and hence have lost their originally definite shapes, with the result that eventually the xenolithic structure degenerates into a mere patchiness [C 221]. Sometimes, instead of the irregular patchiness, a definite banded structure is developed, as a result of flow of the hybrid magma [C 215 & C 211].

Eventually, as the absorption becomes increasingly complete, the excess of dark minerals disappears, and the only sign that one is dealing with a more basic type than the normal granophyre is the presence of irregularly-defined patches containing a greater proportion of felspar and less quartz, the felspar being at the same time more idiomorphic than is normally the case in the granophyre. Such felspathic patches persist for some time, even in the main mass of the granophyre sill, as stated on p. 294. The ill-defined patches may be accompanied by more sharply-defined xenoliths of chilled material (type 1) set in a rock that is otherwise a normal granophyre [C 228, Pl. XVIII, fig. 4].

It should be noted that the most basic types (1 & 2) are not invariably present along the margins of the main intrusion; the actual marginal rocks are then of the slightly more acid type (3).

(2) The minor granophyric intrusions.—It will be convenient to describe these rocks in order from basic to acid. The most basic type is seen in three of the intrusions: namely, in the lower halves of the Craig-y-Castell and the smaller Tyn-y-llwyn masses, and forming the whole of the Waen-Fechan sill. Rocks of this type are dark green, thoroughly basic in composition, and usually rather fine-grained. In many respects they resemble quartz-dolerites, but they are marked off from such rocks by reason of their fine-grained texture, and by the fact that the principal dark minerals are hornblende and biotite, not augite. Still more closely do they resemble some of the rocks found in the basic margin of the Crogenen granophyre, differing from these principally in having a somewhat coarser and more nearly subophitic texture (compare Pl. XIX, figs. 1 & 2).

A specimen from the quarry near Waen-Fechan Farm, at the western end of the Waen-Fechan intrusion, shows felspars to be the largest crystals present [C 234, Pl. XIX, fig. 1]. They are quite idiomorphic, somewhat columnar in habit, and usually are slightly turbid through decomposition (which, however, has not proceeded far enough to disguise their optical properties), and they appear to be near albite in composition. Dark minerals are abundant and varied; fibrous green hornblende is prominent, and a pleochroic chlorite is also plentiful, frequently enclosing rosettes and isolated crystals of a yellow epidote rich in iron. Angular interspaces between the larger idiomorphic felspars are often occupied by a confused network of actinolitic hornblende, set in a matrix of clear felspar-granules. A strongly-pleochroic biotite

also occurs in wisps, fibres, and sheaves, which penetrate alike chlorite, hornblende, and felspar. The mineral was thus formed at a late stage of the consolidation, and it may possibly be pneumatolytic in origin. Such criss-cross biotite never occurs in the normal diabases of the district, but is characteristic of the minor granophyric intrusions.

Quartz is absent from some of the material collected at the quarry, but towards the eastern extremity of the intrusion fairly large granules become abundant. Its associates, however, are calcite and chlorite, which latter invariably wraps round the quartz-grains and sometimes crowds them with small inclusions; some of the primary quartz may, therefore, have grown larger by the deposition of secondary material [C 235 & 245].

The small intrusion capping the hill a short distance to the east of the Waen-Fechan sill was doubtless originally connected to the latter, and in general the two rocks are identical. The hornblende in this case, however, is distinctly bluish, owing to the presence of a higher percentage of soda in the molecule [C 233]. An interesting point is the occurrence of fine-grained xenoliths to the extent of at least a third of the total mass of the rock. The xenoliths consist of chilled basic material, and are similar to those in the neighbouring Tyn-y-llwyn intrusion (see description below, p. 299).

The rock in the lower half of the Craig-y-Castell intrusion approximates to a quartz-diabase in composition, or is intermediate between a quartz-diabase and the markfieldites to be described later. The rocks are somewhat weathered, and do not lend themselves to an exact description. Dark minerals were abundant in large crystals, which are now pseudomorphed by pale hornblende. Twinning and other characters suggest that much, if not all, of this was originally augite [C 276]. Small flakes of pale-green mica are also present, distributed sporadically. Large crystals of plagioclase and orthoclase are present in approximately equal amounts. The plagioclases are, however, largely replaced by secondary products, so that their characteristic lath-shaped outlines and a few traces of albite-twinning alone remain. Primary quartz is fairly abundant in large grains showing lines of fluid inclusions, also in the form of a fine-grained granophyric intergrowth. Granophyric material is almost wanting in the lowest part of the sill, but its amount increases rapidly upwards. Of accessory minerals, apatite is the most abundant; the crystals sometimes contain a narrow zone of pale-green chlorite similarly to apatites described by Dr. J. S. Flett[1] from the albite-diabases of the Newton Abbot district. Granular magnetite is the most abundant iron-ore.

A similar type appears again in the lower half of the smaller Tyn-y-llwyn intrusion, where the rock along the lower contact is

[1] 'The Geology of the Country round Newton Abbot' Mem. Geol. Surv. 1913, p. 60.

noticeable by reason of its high pyrites content [C 238, Pl. XVIII, fig. 6], a feature that is of course not uncommon along igneous contacts.

The upper part of this intrusion and also the lower part of the neighbouring larger Tyn-y-llwyn intrusion consist of coarser-grained and more acid granophyric rocks, which will be described below under the designation markfieldite. With them is associated a considerable amount of a peculiar felspathic, sometimes quartz-free type, which may be conveniently referred to as the Tyn-y-llwyn type. This rock consists mainly of a fine-grained ground-mass composed of a mosaic of felspars, idiomorphic to granular, wrapped round by ragged wisps of chlorite [C 242 & C 312]. Among accessories secondary sphene is abundant, in the form of small, irregular, brownish-grey patches; magnetite and apatite occur as usual; and there are occasional patches of secondary calcite. Distributed irregularly in this fine-grained ground-mass are irregular patches of clear, almost glassy felspars, coarse-grained and free from chlorite [C 226, Pl. XIX, fig. 5]. Between crossed nicols these clear patches are seen to consist of a number of large crystals interlocking quite irregularly, and reminding one of a jigsaw puzzle. These larger crystals show the peculiar streaky and blotched appearance characteristic of perthitic intergrowths, the intergrowth being on a very small scale, wherefore twin striæ are always short and constantly interrupted. This felspar seems to be similar to the

'.... variety of albite which has a dappled or speckled character, with short interrupted twin striæ,'

found by Dr. Flett in some of the Devon albite-diabases (*loc. cit.*).

The rock contains numerous xenoliths of the finer-grained quartz-dolerite, or Waen-Fechan type, which constitutes the lower margin of the intrusion. With increase in the amount of chlorite the Tyn-y-llwyn type passes gradually into the Waen-Fechan type. The occasional absence of free quartz from this Tyn-y-llwyn type is curious, seeing that quartz is a fairly abundant constituent, either as granules or as granophyric intergrowths in rocks such as the quartz-dolerites of Waen-Fechan type which are associated with, and are even more basic than, the Tyn-y-llwyn type itself. Why quartz should locally fail thus suddenly, remains at present uncertain.

These Tyn-y-llwyn rocks appear to be similar to the felspathic diabases from Devon described (with analyses) by Dr. Flett as follows:—

'. . . . pinkish rock that occurs as segregations in typical albite-diabase. The felspar has the dappled appearance that characterizes the microperthites. Good albite-twinning, however, is often seen in the crystals. About 72 per cent. of the rock must consist of alkali-felspar; the other minerals are chlorite, iron-ores, apatite, and a little quartz not certainly primary. The rock is remarkable for . . . . its abundant alkalies . . . .' (*Op. supra cit.* p. 62.)

The Devon rock is compared with one at Newlyn (Cornwall)

'[which] has far too much silica and alkalies and too little lime and magnesia to pass as an ordinary diabase. These bring it much nearer the group of augite-andesites and the spilites, with some analyses of which it is closely comparable.'[1]

The markfieldite type.—This type occurs in the upper half of the Craig-y-Castell mass, which represents the largest and most typical development. It occurs also in the upper part of the smaller Tyn-y-llwyn sill, and again in the middle of the larger Tyn-y-llwyn mass. Finally, it recurs locally along the upper margin of the last-named intrusion.

In the field, rocks of this type are characterized by a regular and large-scale, sometimes columnar, jointing, so that scree-material is composed of great rectangular blocks. These weather grey, and present superficially a deceptive resemblance to the normal diabases of the district; but a closer examination reveals their marked granophyric character. The markfieldite type[2] evidently serves to link up the quartz-dolerites with the normal acid granophyres of eurite type, and every stage of the transition is to be seen. Taking, however, an average specimen of these coarse-grained transitional rocks, one will find it to agree closely both in texture and in composition with the well-known rocks of Groby and Markfield in Charnwood Forest[3]; hence the use of the term markfieldite. It is well known that the Charnwood-Forest rocks have associated with them, usually as separate intrusions, more basic types which show transitions to quartz-dolerites.

The characteristic feature of the markfieldites is the presence of abundant, large, idiomorphic felspars, set in a micrographic groundmass. The granophyric intergrowths are more perfect in this than in any other of the granophyric rocks of the district (Pl. XVIII, figs. 4, 5 & 6), a fact which is of some significance in regard to the genesis of the rocks (see below, p. 303). Besides being more perfect, the intergrowth is usually also much coarser than in the more acid or more basic types. The scale of the intergrowth, however, varies considerably, and sinks in some cases to almost ultramicroscopic fineness [C 241]; such fine-grained intergrowths are more common in the more basic varieties.

Besides taking part in the intergrowth, quartz is present in large granules which are bigger and also more abundant than those in the quartz-dolerites of Waen-Fechan type. Occasionally, these quartz-granules show idiomorphic contours towards chlorite [C 240]; in other examples the quartz of the intergrowth may be in optical continuity with these larger granules.

[1] 'Geology of the Land's End District' Mem. Geol. Surv. 1907, p. 35.

[2] F. H. Hatch, 'Textbook of Petrology' 1909, p. 219.

[3] T. G. Bonney & E. Hill, Q. J. G. S. vol. xxxiv (1878) p. 217, and *ibid.* vol. xlvii (1891) p. 84; also J. J. H. Teall, 'British Petrography' 1888, p. 270; and W. W. Watts, 'Charnwood Forest' Geol. Assoc. Jubilee Vol. ii (1910) p. 717.

Felspar builds highly-idiomorphic crystals which yield rectangular, or sometimes almost quadrate cross-sections. Much of this felspar appears to be orthoclase, but that some is albite is shown by extinction-angles and refractive indices. These felspars usually are slightly turbid with decomposition-products, and in a few cases they are coated with chlorite, which also accentuates their cleavage-traces.

The felspar of the intergrowth shows a fine striation under high powers, and it appears to be soda-orthoclase. Frequently this intergrown felspar is in optical continuity with a narrow mantle surrounding the idiomorphic plagioclases.

Dark minerals are represented by chlorite in some slides, but in others by rather ragged crystals of pale-green uralitic hornblende, sometimes in the form of simple twins. Such fibrous hornblende-crystals frequently show alteration to chlorite in the central parts, and to blotches of brownish-green 'massive' hornblende in the peripheral parts [C 275].

The chlorite is pierced by long narrow crystals of apatite, and by scattered grains and rosettes of almost colourless epidote. Of the accessories, apatite at once strikes the attention by reason of its abundance and size [C 275].

Iron-ores are also abundant, including magnetite in granular aggregates and in perfect octahedra [C 275]; also skeletal crystals of ilmenite in all stages of replacement to leucoxene, and pyrites in cubes distributed sporadically.

As already stated, rocks of markfieldite type pass upwards in the larger Tyn-y-llwyn intrusion without break, into acid fine-grained granophyre, or microgranite, of normal eurite type. At the actual top of the sill there is, however, a recurrence of basic material which is for the greater part chilled. The chilled rock presents a porcellanous appearance in hand-specimens, and under the microscope it is seen to have lost all micrographic structures and to be composed largely of acicular felspars [C 227; Pl. XIX, fig. 6]. An acicular habit of the felspar in marginal rocks was noted by Dr. A. Harker in the Carrock-Fell granophyre.[1]

Genesis of the Granophyric Rocks.

It is quite certain that all the varieties of granophyric rocks are consanguineous, and that they were derived ultimately from a common magma. In fact most of the types present are found within a single mass, that of the larger Tyn-y-llwyn intrusion, in which all transitions from thoroughly acid to almost basic rocks are seen. The variety of types is due partly to deep-seated differentiation, and partly to differentiation in place. The latter process has evidently given rise to the narrow selvages of basic material along both the upper and the lower contacts of the Crogenen granophyre. These selvages are too narrow (only 40 to

[1] Q. J. G. S. vol. li (1895) p. 127.

100 feet thick), and at the same time too regular over many miles, for one to ascribe their origin to the invasion of an early basic intrusion by a later acid intrusion. Further, the transition from basic to acid material is too complete for their periods of formation to have been discontinuous. As already stated, intrusion-breccias are here the exception, the single case observed on Pared-y-Cefn Hir being due to some local movements during consolidation (p. 287). The basic rocks in these selvages, therefore, owe their existence to differentiation in place within the mass of acid material. A noteworthy fact is that the selvages at both the upper and the lower contacts are of approximately equal thickness, and both show the same rock-types, which proves that the differentiation in place was not controlled by gravity in this the largest intrusion of the district. In the same way the larger of the two Tyn-y-llwyn intrusions shows along parts of the upper contact a selvage of basic material that must have resulted from differentiation in place. This absence of control by gravity has an important bearing on the arguments put forward below.

We have next to consider the evidence for deep-seated differentiation. The intrusions may be likened to one-half of a cedar-tree laccolite. The lower intrusions contain, with one exception, a more basic material than those above, and in each single intrusion the material at the bottom is more basic than that at the top. The question then arises whether (1) the intrusions are simply offshoots of a single large mass—a cedar-tree laccolite—in which the basic rocks have resulted from differentiation *in situ*, or whether (2) each intrusion was derived separately from a magma which was in process of undergoing deep-seated differentiation. The latter supposition seems to be the true one, as is apparent from the following considerations.

First, the tongues are of such length, and are separated by such considerable masses of sedimentary rocks, that it is difficult to postulate the convection-currents that would be required to collect together the basic material, supposing the present differences to be solely due to differentiation in place. In this connexion it should be kept in mind that the present southward dip of the tongues is entirely due to tilting subsequent to intrusion: originally the sills must have been horizontal, or nearly so (p. 304), therefore it is not a case of basic material having gravitated into downward-tending offshoots.

Secondly, the position of the highly basic Waen-Fechan intrusion, coming as it does between two acid masses (see fig. 4, p. 289), would be quite anomalous, on the assumption that it resulted from differentiation in place.

We can only suppose, therefore, that the basic rocks in the minor intrusions do not owe their existence to differentiation in place, but that they represent distinct intrusions. Their similarity shows that they were all derived from a common parent magma; but the fact

that the bulk-composition of each intrusion is different from that of the others shows that the parent magma was undergoing progressive deep-seated differentiation. The differentiation followed the normal course, so that from an essentially acid magma successive basic differentiates were drawn off, each less basic than those that preceded. In general, the later or more acidic products were intruded into higher levels than the earlier basic products, the Waen-Fechan intrusion being an exception.

We have still to consider the origin of the stratiform variation within the limits of the individual intrusions. Here the variation was evidently controlled by gravity, since the more basic rocks are found in the lower parts of the intrusions. But it is not clear whether each mass represents a single intrusion in which the variation is due solely to differentiation in place under the influence of gravity, or whether each mass really represents a composite intrusion formed while the progressive deep-seated differentiation process was in active operation. The transition between the various types in the field is so gradual, that it is difficult to see how multiple intrusions can be present. On the other hand, the fact that gravity exerted no control whatever over differentiation in place in the great Crogenen sill makes it difficult to understand why in neighbouring intrusions gravity should exert a dominant effect. Thus, until the rocks have received further study, we prefer to leave open the question as to the origin of the stratiform variation within the limits of each of the minor intrusions. This in no way vitiates our conclusion that the bulk variations in composition between the minor intrusive masses must be due to a progressive deep-seated differentiation, whereas the thin basic selvages along the Crogenen sill must be due to differentiation in place.

The relative perfection in which the graphic intergrowths are developed in the various rocks furnishes an interesting example for study of the part played by a eutectic mixture. The more basic rocks may not contain quartz at all, or only in small amount. So soon as quartz appears, it is for the greater part in the form of micrographic quartz-felspar intergrowths. In the basic rocks the intergrowths are naturally small in amount, interstitial in mode of occurrence, and exceptionally fine-grained; but, when they do occur, they are exceedingly perfect. These interstitial patches represent the last dregs of magma to consolidate, and these last dregs seem to represent a eutectic mixture. With decrease in basicity the intergrowth increases both in amount and in coarseness of grain, until in the markfieldite type (of intermediate composition) the whole rock is largely built up of granophyric quartz-felspar aggregates. The intergrowths are here on a larger scale than in any other of the granophyric rocks, and they are also very perfect (Pl. XVIII,

fig. 4). The progressive deep-seated differentiation had apparently proceeded just far enough to give a felspar-quartz ratio nearest to eutectic proportion.

Deep-seated differentiation did not, however, cease when this stage of a eutectic magma had been reached. The result of further differentiation was accordingly to produce as a last stage an acid magma, the Crogenen granophyre, which was so highly silicated that the amount of silica exceeded that necessary for a quartz-felspar eutectic. The excess of silica crystallized as quartz, and consequently the granophyric structures in the later and most acid rocks are not so perfect as in the earlier rocks of intermediate composition (compare Pl. XVIII, figs. 2 & 4). This seems to show that the formation of eutectics does not exert any dominating effect on the process of differentiation.

(C) Age of the Igneous Rocks.

It was already remarked by Ramsay[1] that the igneous rocks, both acid and basic, were intruded before the main folding movements took place. That this was actually the case is at once suggested in the field by the fact that the igneous masses are intruded approximately along the bedding of the adjacent stratified rocks, and are, therefore, presumably sill-like in character. Further, detailed mapping shows that the igneous masses are repeated by shatter-faults in almost exactly the same manner as the stratified rocks, while the horizon occupied by any given igneous mass is the same, or nearly so, on each side of the faults, thus confirming the sill-like nature of the intrusions.

The fact that the intrusions maintain their sill-like character over wide areas shows that they were intruded prior to the main folding; while the manner in which they are cut and repeated by faults shows that the intrusions also antedated the faulting, both the transverse faulting and the north-east shatter-faulting. But, since the main folding and faulting movements were connected with the Caledonian ('post-Silurian') mountain-building, the age of the intrusions is not thus fixed more precisely than as pre-Devonian.

With regard to the absolute age of the intrusions, the first point to notice is that the granophyres cut through, and are later than, the diabases. The problem limits itself, therefore, to the determination of the age of the granophyres. In this connexion it is highly significant that the granophyres, while they intrude into the highest volcanic rocks of the district—the Upper Acid Series[2]—never invade rocks above this horizon. On Cader Idris a big granophyre-sill, petrographically identical with the Crogenen granophyre, cuts into the rhyolites of the Upper Acid Series, but not into the overlying slates; while the Crogenen sill itself, on the Tyrau-Mawr Gallt-yr-

[1] 'Geology of North Wales' Mem. Geol. Surv. vol. iii, 1st ed. (1866) p. 29.

[2] A. H. Cox & A. K. Wells, 'The Ordovician Sequence in the Cader-Idris District (Merioneth)' Rep. Brit. Assoc. (Manchester, 1915) 1916, p. 424.

Llyn portion of the Cader-Idris range, cuts nearly, but not quite, into this same Upper Acid Series. Now, the granophyres are petrographically similar to, and sometimes in fact almost indistinguishable from, the altered rhyolites of the Upper Acid Series.[1] This suggests that the two sets of rocks—granophyres and rhyolites—are closely related as to age. The Upper Acid Series represents the highest volcanic horizon in the district,[2] no igneous rocks, whether intrusive or extrusive, occurring above this level, nor are there even any distinct ash-bands in the slates above the Upper Acid Series. The absence of any higher volcanic rocks furnishes an additional argument in favour of the close relationship in age between the intrusive granophyres and the extrusive rhyolites.

Now, the age of the rhyolites is known approximately, since the slates immediately overlying the Upper Acid Series contain fossils that suggest a correlation with the *Arctus* Beds of South Wales,[3] that is, with the lower part of the Upper *Dicranograptus* Shales, which are low down in the Bala Series. If, consequently, there is a real connexion between the rhyolites and the granophyres, it follows that the intrusions probably took place in, at the very latest, quite early Bala time.

The intrusions of the Dolgelley and Cader-Idris districts thus fall into line as regards their age, as also in their petrographic characters and mode of occurrence, with certain intrusions in the Lake District—Buttermere, Carrock Fell, etc.—to which a pre-Upper Bala, or earlier age, has been ascribed by Mr. J. F. N. Green.[4]

IV. The Tectonics.

When a district is subjected to severe stress, the usual sequence of events appears to be as follows:—

(1) Intrusion of hypabyssal rocks.
(2) Folding.
(3) Cleavage.
(4) Faulting.

But there is often a certain amount of overlapping as regards the main events, and thus what one may look upon as the 'normal' sequence is more or less modified. A further complication may be introduced owing to later movements having followed (posthumously) lines of earlier movement: wherefore faulting, for instance, may belong to two different periods.

In the Arthog-Dolgelley district both factors—(*a*) overlapping of the different types of movement, and (*b*) repetition of the

[1] It is intended to present a detailed account of the petrology and stratigraphy of these higher rocks in a subsequent communication.

[2] A. H. Cox & A. K. Wells, *op. cit.* p. 424.

[3] T. C. Cantrill, H. H. Thomas, & O. T. Jones, 'The Country round Haverfordwest: Geology of the South Wales Coalfield, pt. xi' Mem. Geol. Surv. 1914, p. 40.

[4] Proc. Geol. Assoc. vol. xxviii (1917) p. 26.

movements—have contributed to modify the general scheme. The sequence of events has here been :—

(1) Tilting of the strata and initiation of the transverse folding. (2) Initiation of strike-faulting. (3) Intrusion of hypabyssal rocks.	Movements anterior to intrusion.
(4) Main folding. (5) Cleavage. (6) Main strike-faulting, with accompanying transverse faulting.	Movements posterior to intrusion.

There can be little doubt that the last three of the phenomena enumerated above were brought about by the widespread 'Caledonian' movement which affected the whole of North Wales. It is quite unnecessary to give here the grounds for this statement. Proof depends upon a consideration of the general structure of North Wales as part of a much more extensive region. But some explanation is needed for placing the first three events in the order given and for ascribing them to the Ordovician Period. Such explanation necessitates a more detailed consideration of the structures observed and of the relationships between them.

(1) Earth-movements anterior to intrusion: the relations of the intrusive rocks to the tectonic features.—The proof that tilting, folding, and faulting were initiated during the Ordovician Period depends upon the relations of the intrusive rocks to the various tectonic features. It has already been shown (p. 305) that petrological and stratigraphical considerations unite in assigning an early Bala date to the intrusions. It has further been demonstrated (p. 304) that the manner in which the intrusions take part in the folding and in the repetition by faulting proves that they antedated the main folding and faulting movements.

When the question is examined in greater detail, however, some interesting facts with regard to the relations between the igneous rocks and the folding become apparent, and show that a certain amount of movement had taken place prior to the intrusions.

First, as regards faulting, one of the strike-faults—the Derwas Fault—quite clearly disappears no fewer than three times against intrusive masses without affecting them, yet in each case it reappears on the opposite side of the intrusion precisely in the position where it would be expected, and it affects then, once again, the sedimentary rocks. Details of the separate occurrences are given below (p. 311). In a fourth case, however, an intrusive mass is affected by the fault, though not to the same extent as the adjacent stratified rocks. Thus, the final conclusion is that the intrusions took place after the movements which gave rise to the Derwas Fault, but that these movements were renewed at some subsequent period. It will be shown later (p. 312) that the Derwas Fault is itself intimately related to the folding.

We may consider next the relationships of the intrusions to the tilting and folding. It has already been shown (p. 281) that the diabase-intrusions, while acting in a general way as sills, yet tend to rest upon the edges of, and to conceal, the stratified rocks in such a way that the sills must obviously transgress southwards on to stratigraphically higher beds. This is the case with the Cae-Einion Gelli-llwyd sill. Similar relations have been shown to prevail in the case of the great diabase-sill of Mynydd-y-Gader, also of the various diabase-masses nearer Dolgelley, which in fact are simply continuations of the Gelli-llwyd sill.

As regards the acid rocks, their intrusion took place later than that of the basic rocks, as is clear from the field relations (p. 282); but the interval between the two series of intrusions was probably not great. Now, in the case of the chief acid intrusion, the northward transgression onto lower stratigraphical levels is still more marked than in the case of the basic rocks. These facts lead to the conclusion that both basic and acid intrusions took place during a period when tilting movements had already established their sway. It appears as if the magmas rose to well-defined hydrostatic levels. In the case of the earlier diabase-intrusions the tilting had only just started, so that the hydrostatic level was nearly, but not quite, parallel to the bedding of the stratified rocks. By the time the later granophyre-magma arose tilting had proceeded still further, with the result that the divergence between the hydrostatic level and the dip of the strata was more pronounced; hence the more obvious transgression of the acid intrusions. The tilting had not yet, however, proceeded so far as to destroy the general sill-like nature of the intrusion. It was, in fact, merely an early forerunner of, and acting in the same direction as, the great folding movements which, later, threw both sedimentary and igneous rocks into their present positions.

Further evidence that the tilting and folding movements had already begun before the igneous rocks were intruded is obtained in the Arthog Valley. There all the strata are affected by a shallow anticline which runs transverse to the normal strike. A diabase-sill on approaching the anticlinal axis transgresses through the Basement Series and down on to the Tremadoc Slates, but resumes its former level so soon as it escapes from the fold. This suggests that folding had begun before intrusion took place, and that the hydrostatic level was independent of the fold as then established. That folding was continued subsequently to intrusion is obvious from the manner in which outcrops are affected.

If the tilting movements had commenced thus early, so that the igneous intrusions overlap, as it were, on to lower horizons in the north, it follows that a similar though less marked overlap should exist between the various divisions of the Ordovician sedimentary rocks themselves. Our knowledge of the detailed stratigraphy of the Ordovician rocks of North Wales is still incomplete; but there is some evidence as to the existence of such an overlap. Its presence in the district between Arenig and Tremadoc has

already been suggested by Prof. W. G. Fearnsides,[1] and it may well be that the remarkable thinness of the *Bifidus* Beds of Arenig Mountain compared with those in the Dolgelley district is due to such an overlap.

With regard to the possibility of the Lower Ordovician rocks having been tilted and faulted as early as Bala time, it must be remembered that by the time the *Arctus* Beds (low down in the Hartfell Group) were deposited, a space of time sufficient for the accumulation of at least 5000 feet of bedded rocks had elapsed since the beginning of the Ordovician Period, and further, that during that time there had been four quite distinct volcanic episodes. The mere existence of such pronounced volcanic activity suggests that earth-movements were in progress.

It may be noted that the possibility of inter-Ordovician folding proceeding in the same general direction as a later and more powerful folding has already been indicated by Mr. J. F. N. Green in the case of the Ordovician rocks of the Lake District.[2] The same author has further adduced evidence that the Ordovician movements in the Lake District were on such a scale that considerable denudation of the volcanic rocks had taken place before an early Bala date.[3]

That elsewhere movements were taking place during Bala time is suggested by the overlaps that occur among the Bala rocks of South Wales.[4]

(2) Movements posterior to the intrusions: (i) The main folding.—Since the district is situated on the southern flanks of the Harlech Dome, the general trend of the strata is determined by that dominating structure. Accordingly, the strike is almost due east and west in the eastern part of the area, gradually swinging round to a north-east–south-west direction in the western part.

The direction of the dip is invariably away from the dome, and remains at about 40° with remarkable uniformity throughout the district, except in the belt of country extending through Bryn Brith and Pared-y-Cefn Hir, where the dip rises to 60° or even 70°.

The Harlech Dome itself is not, however, a simple structure, but is crossed by various minor folds, some of which range into the area now under consideration. The minor folds within this area have a trend that departs but little from due north. The most marked of them are the anticline of the Arthog Valley and the complementary syncline. Both are quite shallow folds, but they are nevertheless sufficiently powerful to cause some oscillation in

[1] Q. J. G. S. vol. lxi (1905) p. 618.

[2] Proc. Geol. Assoc. vol. xxvi (1915) p. 219.

[3] *Ibid.* vol. xxviii (1917) p. 25.

[4] T. C. Cantrill, H. H. Thomas, & O. T. Jones, 'The Country round Haverfordwest: Geology of the South Wales Coalfield, pt. xi' Mem. Geol. Surv. 1914, p. 55; and 'The Country round Milford: *op. cit.* pt. xii' *ibid.* 1916, p. 46.

the outcrops. The synclinal structure is well displayed in the curves of the ridges above Capel Horeb, as viewed from Barmouth Bridge.

(ii) The cleavage.—The effects of cleavage are well marked throughout the district, all the softer beds having been affected: sometimes also some of the harder beds, such as the rhyolitic ashes. On the other hand, the cleavage-stresses have failed to get any grip on the rapid alternations of arenaceous and argillaceous material that build up the Basement Series.

Although all the argillaceous rocks are now in the condition of slates, the cleavage has not usually been sufficient entirely to destroy the fossils. The cleavage-strike usually coincides very nearly with the bedding-strike, but is less susceptible to variations in direction. Evidently, therefore, the cleavage was not established until after the minor folding had taken place. The cleavage-dip usually is steeply inclined to the south, as compared with an average bedding-dip of only 40° southwards. Other things being equal, fossils are therefore more readily obtainable where the beds are more highly inclined, since cleavage and bedding then more nearly coincide. As examples may be cited the locality for the Upper *Dictyonema* Band in the Gwynant Valley and the localities for *Didymograptus bifidus* near Llynau Crogenen.

Although the intrusive rocks are earlier than the cleavage, they rarely show cleavage effects, even along the edges of the smaller intrusions; exceptionally, however, examples of diabase have been found so sheared as to simulate an ash or a felspathic grit. The more highly metamorphosed examples of contact-altered rocks likewise display little or no trace of cleavage.

(iii) The faulting.—The faults may be classified as follows:—

(*a*) Great faults nearly parallel to the strike.
- (i) Normal faults with a downthrow to the south. Examples:—The Derwas, Dolgelley, and Mynydd-Gader North Faults.
- (ii) Reversed faults with an upthrow to the south. The Ceunant-Gwernan Fault.

(*b*) Small faults transverse to the strike.
- (i) Dip-faults, very numerous.
- (ii) North-west faults, examples on Bryn Brith and Gelli-llwyd.
- (iii) North-and-south faults, examples at Llyn Wylfa and the Arthog Valley.
- (iv) Fractures at those points where the strike undergoes a sudden change, as near Pant-y-Piod.

All the varieties of transverse faults are quite small, and so their effects can hardly be shown on the map. In the field they frequently give rise to small notches where they cross the harder bands.

The greater faults that keep more nearly parallel to the strike deserve more detailed mention. Their exact relationships one to the other, to the folding, and to the intrusive rocks, are rather

complicated; faulting has evidently been in operation along the same lines on various occasions, with the result that the same fault appears now earlier, now later, than the intrusive rocks. Accordingly, a description of each of the main strike-faults will be given.

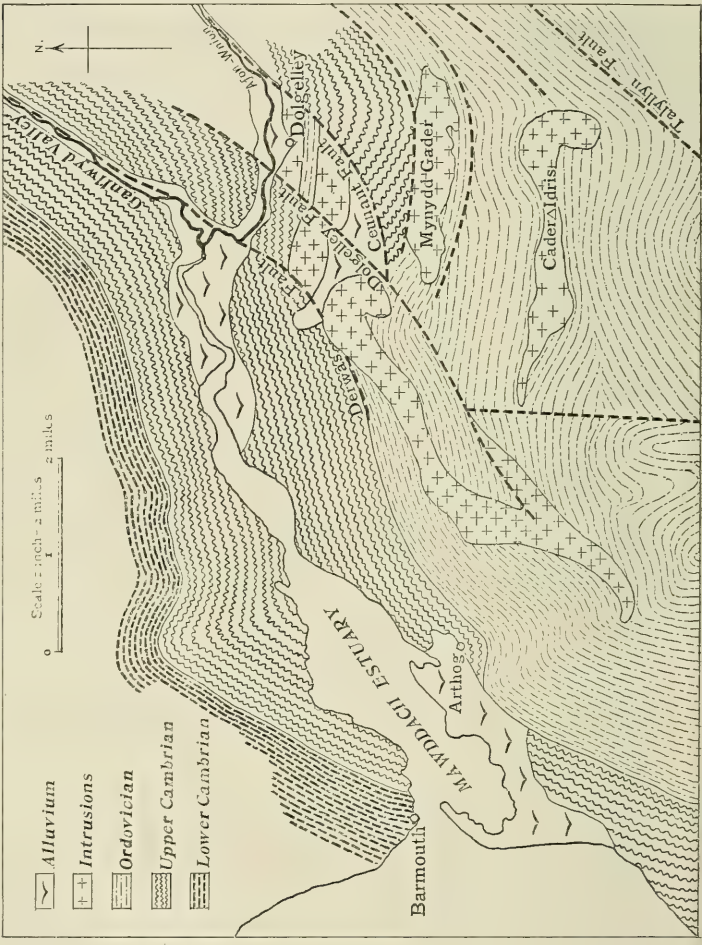


Fig. 7.—Geological sketch-map of the Arthog-Dolgelley district, illustrating the relationships between the strike and the faults, intrusions, and main river-valleys.

(i) The Derwas Fault.—This fault was first mentioned by Mr. Lake & Prof. Reynolds as bringing Dolgelley Beds against Ffestiniog Beds, and acting as a normal fault with a downthrow to the south-east.[1] Those authors were uncertain as to whether the fault actually shifted the neighbouring diabase-intrusion, but they

[1] Q. J. G. S. vol. lii (1896) p. 513.

found that in any case the diabase was not shifted to the same extent as the sedimentary rocks. In part, therefore, the fault was anterior to the intrusion. That movement was renewed later along the same line, but subsequently to intrusion, is suggested by the fact that there is a marked valley, or gorge, along the line of fault where it passes across the igneous mass.

As we trace the fault westwards it gradually transgresses into higher strata, and then disappears beneath a prolongation of the intrusion at Maes Angharad. Here, however, the intrusion is quite small, and cannot conceal any great thickness of sedimentary rocks. But, since the rocks on the north side of the intrusion belong to the Dolgelley Beds and those on the south side to the Arenig Basement Series, there is obviously extensive faulting underneath the intrusion, the whole of the Tremadoc Slates being cut out, with the result that some 900 feet of strata are missing.

Still farther westwards, across the Tyn-y-llwyn depression, Tremadoc Slates are in contact with the Lower Acid Series, the Basement Beds being now cut out in their turn. Again the downthrow is to the south, but again no fault is actually to be seen, as it is covered by the granophyre-intrusion. The lower margin of the granophyre is here almost coincident with the former line of fault, wherefore a passing inspection of the map would suggest that the granophyre is actually bounded by a fault. This is, however, not the case, and the granophyre is not in the least affected by the fault, as is clearly proved by the markedly metamorphosed condition of the adjacent Tremadoc Slates.

It is true that a little south of the line of older faulting there is a zone in the granophyre marked by abundant quartz-veins, which probably originated during some later movement along a line parallel and close to the original line of weakness. Thus the relation of the Derwas Fault to the granophyre falls into line with the relation of the Derwas Fault to the diabase.

Yet farther west, towards Waen Fechan, the fault emerges from beneath the granophyre, and its effect is to cut out the Basement Series all the way to Cae-Einion beyond the Gwynant Valley. Along this stretch, however, the fault twice disappears beneath an intrusion—the Cae-Einion Gelli-llwyd sill—which is not itself affected by the fault on either occasion. The westernmost disappearance of the fault at Cae-Einion is final; it evidently dies away in a westerly direction. Altogether. then, the fault disappears at least four times beneath different intrusive masses, so that there can be no doubt as to the earlier age of the fault relative to the intrusions.

In the western portion of its course, where it is so frequently concealed beneath intrusive rocks, the Derwas Fault naturally makes no distinctive physical feature; but farther east its line lies along a marked hollow which descends past Glyn-Malden, and opens towards the silted-up head of the Mawddach Estuary at the junction of the Wnion and Mawddach Valleys (fig. 7). Now, from any of the numerous favourable view-points the opening of the

fault-hollow is seen to be aligned with the deep and straight rift-like Ganllwyd Valley (valley of the middle Mawddach) which debouches on the opposite side of the estuary valley. This rift-like valley evidently represents the north-eastward prolongation of the Derwas Fault. But, while the fault south of the estuary extends in a direction north-east and east-north-east, the fault north of the estuary runs more nearly north-north-east. The fault therefore swings round in the same manner as, but more rapidly than, the strike of the sedimentary rocks as they follow the trend of the Harlech Dome. The fault is thus a true strike-fault, completed, so far as concerns its eastern portion, during the movements that gave rise to the main dome, but initiated, at least along its western portion, during a much earlier period, before the igneous rocks (of Bala or pre-Bala age) were intruded.

(ii) The Dolgelley Fault.—This fault runs parallel to, and about half-a-mile south of, the Derwas Fault. Its course determines the direction of a deep valley which (south of the Wnion Valley) is bigger and more persistent than the hollow caused by the Derwas Fault. Like the latter, it acts as a normal fault, throwing down to the south-east. But, unlike the Derwas Fault, it evidently cuts and displaces the intrusions. Mr. Lake & Prof. Reynolds [1] considered, however, that along this fault also the main movement took place prior to the intrusion, and that movement was subsequently reversed. We shall produce below (p. 313) further evidence bearing on this point.

(iii) The Mynydd-y-Gader North Fault.—One other fault which appears to be earlier than the intrusions is that along the northern front of Mynydd-y-Gader. It cuts out the Basement Series and also more and more of the Upper Cambrian rocks as it is followed eastwards, until eventually some 1500 feet of rock are missing. Along much of its course it is concealed by diabase material, often perhaps only in the form of screes, and it is not possible to state in this case whether or no the fault affects the intrusion itself. As with the Derwas and Dolgelley Faults, the downthrow is to the south.

(iv) The Ceunant Fault.—The remaining fault—the Ceunant Fault [2]—is in a quite different category. It acts as a repeating fault, throwing up the rocks on its south side, and in this way differs from the faults so far mentioned, which act as normal faults throwing down to the south. The extent of the throw is apparently 3000 or 4000 feet in places. This semblance of a large vertical throw is, however, probably due to a lateral shift, rather than to a true vertical throw, just as in the case of the Llyfnant Fault, 20 miles to the south, described by Prof. O. T. Jones & Mr. W. J. Pugh.[3]

[1] Q. J. G. S. vol. lii (1896) p. 521. [2] *Ibid.* p. 512.
[3] *Ibid.* vol. lxxi (1915) p. 373.

The Ceunant Fault is probably a continuation of the one that determines the long straight valley of the Wnion above Dolgelley (fig. 7, p. 310), and which itself is a branch of the great Bala Fault. The Wnion Valley leaves the fault-line near Dolgelley: the line is continued, however, by the gorge of the Lower Ceunant, and then, after an interval in which there is merely a hollow, but not an actual gorge, it is further continued by the line of the deeply-cut Gwernan Valley.

At Llyn Gwernan the Ceunant and the Dolgelley Faults converge, and ultimately coalesce under the alluvial deposits. The result is that the two faults, throwing in opposite directions, almost neutralize one another. The Ceunant Fault is the stronger of the two, and accordingly the total effect is that of a slight repetition, the fault-line being continued for another 5 miles along a straight and deep valley, which eventually ends westwards as the fault gradually dies away.

The Ceunant Fault is clearly later than the intrusions, as regards both its eastern and its western portions. Both sedimentary and intrusive rocks are involved in a crush-breccia along the course of the Lower Ceunant. Farther west the Crogenen granophyre is repeated by the fault: the apparent vertical throw, determined from relative positions of the upper boundary of the sill on Mynydd Caer-go and Tyrau Mawr, being here about 1500 feet.

The manner in which the Dolgelley and Ceunant Faults coalesce and neutralize each other suggests that both were active at the same time, which must have been later than the intrusions, the result being to let down a wedge of country between the two faults. But, judging from the manner in which the Dolgelley Fault keeps parallel with the Derwas Fault, which was in part clearly earlier than the intrusion, it seems reasonable to assume that the Dolgelley Fault was itself active at more than one period.

It is highly significant that all four faults—the Derwas, Dolgelley, Ceunant, and Mynydd-y-Gader North Faults—enter the district on the east as strongly-marked features and with large throws, and that they gradually diminish in power westwards, finally disappearing within the limits of the area mapped. The longitude where these faults disappear coincides with that at which the strike changes from an approximately east-and-west direction to one more nearly north-east and south-west.

It is further noticeable that, just as the faults diminish westwards, so likewise do the intrusions, of which only one or two examples extend more than a mile beyond the longitude at which the faults die out. Moreover, in regard to the extrusive rocks, it has already been shown that the thickness of the Lower Acid Series decreases considerably to the west, and the same statement seems to apply to the higher volcanic series.

The various phenomena, namely: (i) change of strike, (ii) disappearance of faults, (iii) disappearance of intrusions, and

(iv) thinning of volcanic rocks, are evidently interconnected. The connexion between (i) and (ii) is readily explained. The north-east and south-west, or 'Caledonian' strike, may be regarded as that typical in North Wales; wherever deviations from that strike occur, faulting at once sets in. The connexion between (ii) and (iv) is also clear. Further, the position of the intrusions was doubtless determined by the rigid cover of volcanic rocks; where the cover becomes less massive, and consequently less rigid, the intrusions decrease in number and size. Accordingly, it appears reasonable to assert that (*a*) the position of the faults was determined by the change of strike, or in other words, by the direction of the earth-movements, and (*b*) the position of the intrusions was determined by the volcanic rocks. The question then arises, did the position of the volcanic rocks (with their associated intrusions) determine the direction of subsequent earth-movements, or does the reverse hold, that early earth-movements controlled the disposition of the igneous rocks? The available evidence all points to the latter being the case. It has already been shown that the tilting movements which were ultimately to produce the Harlech Dome were already in progress before the pre-Bala intrusions arose, and that the faulting had likewise been initiated at this early date. It seems, therefore, a reasonable supposition that the course of these Ordovician movements determined the position of the volcanic outbreaks and the lines which the later movements were to follow.[1]

The relationships between the various structures, between the tilting and the intrusions, the intrusions and the Derwas Fault, the Derwas Fault and the Harlech Dome, and other faults, go to show that the Harlech Dome must have had a very long period of growth, beginning at least as early as Ordovician time. They further show that the so-called post-Silurian or 'Caledonian' movements were, in reality, spread over a long period. In fact, it is quite possible that movement was continuous, or almost so, from Cambrian to Devonian time. The cumulative effect we speak of as due to 'post-Silurian' movement. But, in speaking thus, we are apt to lose sight of the long drawn-out character of the movement. In fact, to assign certain of the effects to a 'post-Silurian' movement is equivalent to referring to, say, Cretaceous time, when we really mean Mesozoic time.

The fault-system and the Mawddach Estuary.—A point of some interest is the relation of the Wnion Valley and its continuation, the Mawddach Estuary, to the fault-system. Above, or north-east of Dolgelley, the Wnion Valley follows a straight course for some miles. This line is evidently a continuation of the Ceunant repeating fault, and it meets and coalesces with the

[1] See W. W. Watts, 'The Igneous Rocks of the Welsh Border' Proc. Geol. Assoc. vol. xix (1905) p. 174; and W. G. Fearnsides, 'North & Central Wales' Geology in the Field, Geol. Assoc. Jubilee Vol. (1910) p. 810.

great Bala Fault near Drwsynant (6 miles above Dolgelley), where there is an old valley right over the watershed into the valley of the Dee and Bala Lake.[1]

Near Dolgelley, however, the Wnion Valley suddenly leaves the main fault-line (which is continued by the Ceunant Gorge) and follows a winding course for some 2 miles towards Penmaenpool (fig. 7, p. 310). This winding valley must cross the line of the Derwas Fault (with its continuation up the Ganllwyd Valley) and also the line of the Dolgelley Fault, which is probably continued north-eastwards, swinging round in the same manner as, and parallel with, the Derwas Fault. In neither case, however, is the course of the Wnion Valley affected by the fault. Thus the lower part of that valley and its continuation—the head of the Mawddach Estuary—are independent of the faulting. This local absence of direct relationship finds a striking parallel some 15 miles away to the south, in the case of the Dovey Valley and its estuary. The course of the Dovey Valley has been shown by Prof. O. T. Jones & Mr. W. J. Pugh[2] to be independent of the faulting as regards the stretch which lies near and just below Machynlleth, although it is actually crossed by strike-faults. On the other hand, the higher reaches of the Dovey Valley, like the corresponding parts of the Wnion Valley, are determined by the faulting. It is probably more than a coincidence that in each case the only important town of the valley—Dolgelley in the one case, Machynlleth in the other—should stand just at the point where the valley leaves the fault-line.

V. Comparison with other Areas.

(1) The Upper Cambrian.

The sequence of the Upper Cambrian rocks, as developed in the Arthog–Dolgelley district, compares almost exactly with that in the Arenig[3] and Tremadoc[4] districts. The developments of the Ffestiniog and Dolgelley Beds are so similar in the different areas that no further comment is needed. In regard to the Tremadoc Slates the comparison is also very close, as is seen from the following synopsis:—

Arthog.	Arenig.	Tremadoc.
Upper Pencil-Slates. (Upper *Dictyonema* Band.)	Absent in part.	Garth-Hill Beds.
Asaphellus Flags & Shales.	*Shumardia* Beds. *Asaphellus* Flags.	Penmorfa Beds. Portmadoc Flags.
Lower Pencil-Slates.	*Bellerophon* Beds.	Moelygest Beds.
Lower *Dictyonema* Band.	*Dictyonema* Band.	*Dictyonema* Band.
Niobe Beds.	*Niobe* Beds.	*Niobe* Beds.

[1] P. Lake, Geol. Mag. 1900, p. 141.
[2] Q. J. G. S. vol. lxxi (1915) p. 378.
[3] W. G. Fearnsides, Q. J. G. S. vol. lxi (1905) p. 614.
[4] *Id. ibid.* vol. lxvi (1910) p. 155.

On account of the similarity of the sequences, we have so far as possible avoided the introduction of new stratigraphical terms.

The highly-fossiliferous band in the higher part of the *Asaphellus* Flags and Shales of Llyn Wylfa, near Arthog, seems to correspond exactly in horizon with the famous fossiliferous band of Penmorfa, Tremadoc. The occurrence of a *Dictyonema* Band above the *Asaphellus* Beds does not seem previously to have been recorded.

(2) The Ordovician.

(*a*) Correlation with the sequence at Arenig Mountain.—The Ordovician rocks of the Arthog–Dolgelley district naturally find their nearest equivalents in the Arenig area,[1] which lies only 12 miles away to the north-east. There are, however, certain important differences.

The Basement Series at Arthog evidently corresponds to the Basal Grits and *Extensus* Flags of Arenig. The actual basal grit is an inconstant member of the series, both at Arthog and at Arenig. It is noteworthy that the representatives of this series in the Lleyn Peninsula—the Tudwal Sandstones[2]—are considerably thicker than at Arthog or Arenig, although the lithology is very similar.

The lower part of the Lower Acid Volcanic Series is in part represented at Arenig by the *Calymene* Ash. The marked thickening of the volcanic rocks towards the east in the Arthog area and their greatly inferior thickness at Arenig, together with the absence of lavas in the latter area, indicate that the focus of igneous activity lies between the two localities, probably not far from Dolgelley. Towards the north-west these lowest volcanic rocks appear to die out altogether, as no trace of such a series is found in the Lleyn Peninsula, where the Tudwal Sandstones are succeeded by a thick series of mudstones.

The lowest part of the Pont Kings Slates is almost certainly equivalent to the *Hirundo* Beds at Arenig, and in both districts the junction between the Arenig and the Lower Llanvirn Series lies in a shale-band. Again, ash-bands occur in and above the slates in both cases, but are more important at Arthog, where they form a continuation of the lower rhyolitic ashes.

The *Bifidus* Beds, although lithologically identical in both areas as regards the slates, yet show certain noteworthy differences in development. At Arthog the Moelyn Slates, together with the Crogenen Slates, attain a maximum thickness of 450 feet, whereas at Arenig the *Bifidus* Slates are only 20 to 30 feet thick. The peculiar Bryn Brith Beds, which come in between the two series of slates in the Arthog district, are either absent at Arenig, or are represented by a thin ash, there grouped with the *Hirundo* Beds. These differences are probably accounted for by an overlap within

[1] W. G. Fearnsides, Q. J. G. S. vol. lxi (1905) p. 618.

[2] T. C. Nicholas, *ibid.* vol. lxxi (1915) p. 107.

the *Bifidus* Beds, which becomes more pronounced towards the north and east.

The Cefn Hir Ashes, with the overlying Lower Basic Series, are clearly equivalent to the Lower Platy Ashes and Agglomerates with the overlying Lower Andesitic Series of Arenig.

(*b*) Correlation with the Shropshire sequence.—The Arenig strata of the district can only be correlated in a general way with those of Shropshire,[1] and various important differences are found. On the other hand, a close comparison may be drawn between the Llanvirnian Series in the two districts. The arenaceous beds—the Stiper Stones and the succeeding Lower Mytton Flags (composed of alternations of arenaceous and argillaceous material)—probably correspond to the Basement Series at Arthog; but the Shropshire strata are much thicker than their equivalents in the Cader-Idris and Arenig districts. In the succeeding argillaceous beds of Shropshire, which are likewise of considerable thickness, nothing corresponding to the Lower Acid Volcanic Series occurs. The Shropshire sequence, therefore, resembles that in the Lleyn Peninsula, the two districts being symmetrically placed with reference to the Cader-Idris–Arenig line, along which the thinner, more volcanic facies of the Arenig strata is developed.

Above the *Hirundo* Zone, however, the successions in the Arthog and Shropshire districts are very similar. The junction between the *Hirundo* and the *Bifidus* Zones occurs in both areas in a shale-band, the Pont Kings Slates and the Hope Shales respectively. The 'China-stone' Ashes above the Pont Kings Slates are represented by exactly similar ashes among the Hope Shales. The Moelyn and Crogenen Slates together evidently correspond to the main mass of the Hope Shales. The Cefn Hir Ashes and Lower Basic Volcanic Series are correlative with the Stapeley Andesitic Ashes and Lavas. Shale-bands containing *Didymograptus bifidus* occur intercalated in both volcanic series, while the composition of certain porcellanous ashes is identical in both areas.

(*c*) Correlation with the sequence in South Wales.—The sequence in South Wales compares more closely with that in Shropshire than with the sequence at Arthog. Again, only a general correspondence exists between the sequences of North and of South Wales, so far as the Arenig is concerned; whereas, again, the Llanvirnian allows us to institute a close comparison.

In South Wales,[2] as in Shropshire, the Arenig succession is much

[1] C. Lapworth & W. W. Watts, 'The Geology of South Shropshire' Proc. Geol. Assoc. vol. xiii (1894) p. 317; and 'Shropshire' Geol. Assoc. Jubilee Vol. (1910) p. 751; also section by C. Lapworth in the 'Summary of Progress for 1915' Mem. Geol. Surv. 1916, p. 37.

[2] T. C. Cantrill & H. H. Thomas, 'The Country round Carmarthen: Geology of the South Wales Coalfield, pt. x' Mem. Geol. Surv. 1909, p. 9; also D. C. Evans, 'The Ordovician Rocks of Western Carmarthenshire' Q. J. G. S. vol. lxii (1906) p. 603; and A. H. Cox, 'Geology of the District between Abereiddy & Abercastle' *ibid.* vol. lxxi (1915) p. 283.

thicker than along the Cader-Idris–Arenig line. As in the other localities mentioned, the succession is essentially arenaceous below and argillaceous above. Lithologically similar beds occur at approximately the same horizons in South Wales and at Arthog; but the differences in thickness are very marked, and the actual details do not correspond exactly. In North Pembrokeshire, the Trefgarn Volcanic Series[1] possibly represents the Lower Acid Volcanic Series; but the palæontological evidence is as yet incomplete, and the two series are chemically dissimilar: that at Arthog being essentially rhyolitic, while the North Pembrokeshire volcanics are keratophyres[2] of intermediate composition.

The junction of the Arenig and Llanvirnian Series in South Wales, as in the other districts considered, is among shales or slates, and is not marked by any great lithological change. The 'China-stone' Ashes near the base of the Lower Llanvirnian at Arthog have their exact equivalents at the corresponding horizon in South Wales (for references, see p. 272); while the ashy grits of Bryn Brith appear to be at about the same horizon as the ashy sandstones which are intercalated in the lower half of the *Bifidus* Slates over parts of Carmarthenshire.[3]

The *Bifidus* Slates are overlain by volcanic rocks in both districts, the Cefn Hir Ashes and Lower Basic Series in the Cader-Idris district, the rhyolitic rocks of Abereiddy[4] and Ramsey Island in Pembrokeshire. There is no doubt that volcanic activity broke out simultaneously in the Arenig, Cader-Idris, Shropshire, and Pembrokeshire districts; the horizon at which the volcanic rocks begin is in all cases richly fossiliferous. Yet the lavas in North Wales and Shropshire are basic to intermediate in composition—spilites and andesites; while those of Pembrokeshire (Abereiddy and Ramsey Island) are rhyolitic.

VI. Summary and Conclusions.

South of the Harlech Dome, between the Mawddach Estuary and the northern flanks of Cader Idris, a succession has been established extending from Upper Cambrian (*Lingula* Flags) to beds of Llandeilo age.

The *Lingula* Flags—Ffestiniog and Dolgelley Beds—show a typical development, and are succeeded by Tremadoc Slates. The Tremadoc Slates contain no volcanic rocks of any kind. On the contrary, their development corresponds closely with that seen north of the Harlech Dome in the Arenig and Tremadoc areas, and most of the subdivisions that have been distinguished north of the Dome can be recognized again in the south.

[1] H. H. Thomas, in 'The Country round Haverfordwest: Geology of the South Wales Coalfield, pt. xi' Mem. Geol. Surv. 1914, p. 21.

[2] *Ibid.*; also A. H. Cox, Q. J. G. S. vol. lxxi (1915) p. 314.

[3] T. C. Cantrill & H. H. Thomas, 'The Country round Carmarthen: Geology of the South Wales Coalfield, pt. x' Mem. Geol. Surv. 1909, p. 25.

[4] A. H. Cox, *op. supra cit.* p. 302.

A minor point is the occurrence of *Dictyonema sociale* at two distinct horizons in the Tremadoc Slates. The Lower *Dictyonema*-Band immediately overlies the *Niobe* Beds, and is therefore on the same horizon as the band at other well-known localities; the Upper Band occurs about 500 feet higher in the series, and above the *Asaphellus* Beds.

The relationship of the Ordovician System to the underlying Tremadoc is obscure. Although neither actual transgression nor discordance of dip can be observed, the lithological characters of the beds are quite distinct, and they suggest the presence of a break in the sequence.

The Ordovician succession commences with a thin Basement Series, consisting of felspathic grits and quartzites, with associated banded grits and flags which show alternations of argillaceous and arenaceous material.

These Basement Beds are succeeded by a volcanic series, the Lower Acid Series, which shows considerable lateral variation. The series is thickest in the east, where it consists mainly of rhyolitic tuffs, with rhyolitic lavas in the south-east. The tuffs and lavas thin away rapidly westwards, and coincident with this thinning, slate-bands—the Pont Kings Slates—appear among the volcanic rocks in the western part of the district.

The slates yield a mixture of extensiform and tuning-fork graptolites, showing them to be in part of Arenig age (zone of *Didymograptus hirundo*) and in part of Lower Llanvirn age.

The *Bifidus* Beds consist mainly of fossiliferous slates separated into two bands—the Moelyn and the Crogenen Slates—by a group of ashy grits, the Bryn Brith Beds. In the eastern part of the district these grits overlap the Moelyn Slates, and rest directly upon the rhyolitic rocks of the Lower Acid Series. The peculiar lithological characters of the group and its relations to underlying groups are probably accounted for by deposition against the flanks of a volcanic cone which was undergoing rapid erosion.

A great thickness of volcanic rocks succeeds the main mass of the *Bifidus* Slates. The volcanic rocks begin with massive ashes—the Cefn Hir Ashes—of andesitic composition. Thin shale-bands still yielding *Didymograptus bifidus* are associated with these ashes. The Cefn Hir Ashes are followed by the Lower Basic Series, a great thickness of spilites (often as pillow-lavas), with associated ashes and subordinate slate-bands.

The sequence of these various Ordovician deposits is essentially similar to that at Arenig Mountain, the main difference between the two areas being the greater thickness at Dolgelley of the Lower Acid Series and of the *Bifidus* Beds. A close comparison may also be drawn between the Llanvirnian rocks of the Arthog–Dolgelley district and those of Shropshire and South Wales.

Intrusive rocks, both acid and basic, occur at all horizons in the stratigraphical succession, in the form of sills or laccolites. Individual sills tend to trangress northwards on to lower stratigraphical horizons.

The earlier intrusions were diabases of normal Welsh type. These were followed by a set of intrusions derived from a granophyric magma which was undergoing progressive and deep-seated differentiation. Various basic and intermediate differentiates were drawn off, and intruded in order as a set of minor intrusions. The minor intrusions together contain all transitions, from thoroughly basic rocks with little or no quartz, through intermediate rocks—markfieldites—to thoroughly acid rocks. In general, the rocks in each sill are more basic than those in the sills above; further, there is a stratiform variation within the limits of individual intrusions, the more basic rocks being always at the bottom. These minor intrusions were followed by the main mass of acid material—the Crogenen granophyre—which forms a laccolite over 1200 feet thick.

Structural and petrographical considerations point to a pre-Upper Bala age for all the intrusive rocks.

The area is dissected by faults of three main types, the most important being those that are almost parallel to the strike. Dip-faults and north-west faults are of subordinate importance.

The process of tilting, folding, and faulting commenced during the Ordovician Period. These movements were followed by the intrusion of the hypabyssal rocks. The main folding, the cleavage, and the main faulting were posterior to the intrusion of the igneous rocks, but followed along the same lines as the earlier movements.

In conclusion, we wish to express our indebtedness to Prof. S. H. Reynolds for the loan of his 6-inch geological maps of the country near Dolgelley; the lines on his maps[1] have been adopted, with but slight modification, in the preparation of Pl. XX. We are indebted to Mr. Frank Raw and to Dr. V. C. Illing for their identifications of certain of the Tremadoc trilobites; to Mr. John Pringle for examining many of the graptolites; and to Mr. N G. Blackwell for photographs. We wish also to thank Mr. and Mrs. Griffith Pugh, Penrhyn-gwyn, for their hospitality during our visits to the district. One of us (A. H. C.) wishes to acknowledge his indebtedness for grants from the Royal Society, and from the Dixon Fund of the University of London, which helped to defray a part of the expenses during the earlier stages of the investigation.

EXPLANATION OF PLATES XVI–XX.

Plate XVI.

View looking eastwards across the Gwynant Valley to Graig-Llwyd.

The sky-line corresponds to part of the line of section, CD, fig. 1, p. 258.

a. Ffestiniog Beds. *bb*. The Craig-y-Castell markfieldite intrusion covering Dolgelley Beds, but not extending down into the valley. *c*. Graig-Llwyd, the *Niobe*-Beds scarp. *d*. *Asaphellus*-Beds scarp. *e*. Scarp of Waen-Fechan intrusion. (See pp. 255, 262, 289.)

[1] P. Lake & S. H. Reynolds, Q. J. G. S. vol. lii (1896) pl. xxiv; and *ibid.* vol. lxviii (1912) pl. xxxv.

Plate XVII.

View looking eastwards across Llynau Crogenen to Pared-y-Cefn Hir.

a. Scarp made by the 'China-stone' Ashes. *b*. Bryn Brith. *c*. Pared-y-Cefn Hir, andesitic ashes, with granophyre on the steep dip-slope. *d*. Hollow on granophyre-outcrop; on the extreme right in the middle distance is Mynydd Caer-go, the scarp of the Lower Basic Series. Gelli-llwyd is seen in the background on the right. In the foreground are grass-covered *Bifidus* (Crogenen) Slates with diabase-sills on each side. The *Bifidus* Slates run along the wall leading from the lake under the scarp of Cefn Hir. (See p. 279.)

Plate XVIII.

Fig. 1. Granophyre [C 200]. Pen Moelyn. Crogenen intrusion. Acid granophyre of Crogenen type, granophyric structures moderately well developed; microporphyritic albite with rim of orthoclase. Crossed nicols. × 20. (See pp. 291, 294.)

2. Granophyre [C 203]. Hafod-dywyll, Gwynant Valley. Crogenen intrusion. Similar to the above; rounded patches consisting mainly of interlocking grains of quartz with a small amount of felspar (ocellar structure) surrounded by fringes of extremely fine-grained micropegmatite, the whole set in a microgranitic ground-mass. Crossed nicols. × 20. (See pp. 291, 294.)

3. Spherulitic granophyre [C 206]. Nant-y-Gwyrddail. Southern margin of Crogenen intrusion. Spherical patches of radiate fine-grained micropegmatite, almost free from dark minerals; the spherulites are set in a finely granular ground-mass richer in dark minerals. Crossed nicols. × 20. (See p. 294.)

4. Coarse granophyre, near markfieldite [C 208]. Tyn-y-llwyn intrusion. Coarse-grained, with granophyric structures well developed. Crossed nicols. × 20. (See pp. 294, 300.)

5. Markfieldite [C 240]. Craig-y-Castell intrusion. Coarse-grained granophyric rock showing idiomorphic albites, granular quartz, and isotropic chlorite set in a micropegmatitic ground-mass. Crossed nicols. × 20. (See pp. 300, 304.)

6. Markfieldite, near Waen-Fechan type [C 238]. Smaller Tyn-y-llwyn intrusion. Highly idiomorphic albites, granular quartz, with chlorite, pyrites, and ilmenite, set in a ground-mass of extremely-fine, almost ultramicroscopic micropegmatite. Crossed nicols, × 20. (See pp. 298, 300.)

Plate XIX.

Fig. 1. Basic rock [C 234]. Quarry, western end of Waen-Fechan intrusion. The rock is comparable with a diabase. Texture originally sub-ophitic. Idiomorphic albites with interstitial chlorite (grey), large plates of ilmenite, abundant wisps of biotite, and occasional blebs of quartz. Ordinary light. × 20. (See pp. 289, 297.)

2. Basic marginal rock [C 220]. Lower or northern margin of Crogenen intrusion, 600 yards east-north-east of Waen Fechan. Felspar mainly orthoclase. Abundant dark minerals include chlorite as wisps and fibres, and some ilmenite as plates. Quartz rare. Near the lower margin occurs a twinned crystal of allanite, associated with calcite and quartz. Ordinary light. × 20. (See p. 295.)

3. Basic marginal rock [C 223]. Lower margin of Crogenen intrusion, stream near Waen Fechan. Microporphyritic albite with outgrowth (above) of fine-grained micropegmatite. Dark minerals abundant; strongly pleochroic hornblende and brown biotite in wisps and fibres. Ordinary light. × 20. (See p. 295.)

Fig. 4. Granophyre [C 228]. Near Craig-y-Castell. The rock is intermediate between the markfieldite and eurite types. Idiomorphic albites and granular quartz surrounded by fine-grained micropegmatite; above a xenolith, fine-grained and more basic, consisting of felspar, chlorite, and magnetite, all granular. Crossed nicols. × 20. (See p. 297.)

5. Felspathic modification, Tyn-y-llwyn type [C 226]. Smaller Tyn-y-llwyn intrusion. The ground-mass consists mainly of small felspars, some idiomorphic, some granular, with rather abundant chlorite. Also groups of larger irregular crystals of a curiously-twinned felspar comparable with chequer-albite. In the illustration these larger crystals almost fill the field. Crossed nicols. × 20. (See p. 299.)

6. Chilled marginal rock [C 227]. Top of the larger Tyn-y-llwyn intrusion. Felspar-phenocryst in a matrix composed mainly of acicular felspar and interstitial chlorite. Above is still finer-grained material, more granular in texture. Crossed nicols. × 20. (See p. 301.)

Plate XX.

Geological map of the Arthog–Dolgelley district, on the scale of 3 inches to the mile, or 1 : 21,120.

Discussion.

Prof. W. W. Watts desired to congratulate the Authors on both the subject-matter of the paper and the manner of its presentation to the Society in the time at their disposal. He thought that they had been wise in clearing up the structure of the foothills before dealing with the main range, although the saturation of the rocks with intrusive material rendered it by no means easy to unravel the succession and structure there.

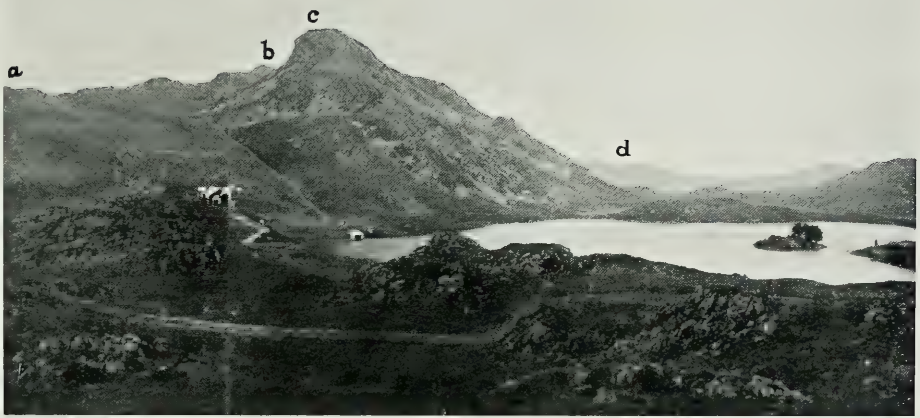
It was perhaps to be expected that the Tremadoc succession should fit in with that at Arenig and Portmadoc; but the appearance of a new *Dictyonema* Band was of interest, and he asked whether the species agreed with those of the Lower Band. The Authors appeared to have given satisfactory evidence that there was no Tremadoc vulcanicity; but he wished to hear the reasons which had led to the conclusion that the main period of intrusion was pre-Silurian, as such a conclusion was not in accordance with his own experience. The series of intrusive rocks ranging from basic to acid worked out by the Authors was of interest in connexion with the stratification of the intrusions—a phenomenon noticed by Dr. A. Harker in the Lleyn and by the speaker in Shropshire. The resemblance of some slides shown to the 'syenite-' group in Charnwood Forest was remarkable and illuminating, as the rocks in that area also had a wide range in composition. Finally, the speaker called attention to the general form of the intrusive masses as shown in the sections on the screen.

Mr. J. F. N. Green said that, as he had described a Bala unconformity in the Lake District and had there referred a number of intrusions, previously said to be Devonian or Tertiary, to a pre-Upper Bala age, he was naturally interested to learn that, in the

N. G. B. photo.

VIEW LOOKING EASTWARDS ACROSS THE GWYNANT VALLEY TO GRAIG-LLWYD.

[a=Ffestiniog Beds. bb=Craig-y-Castell markfieldite. c=*Niobe* Beds. d=*Asaphellus* Beds. e=Waen Fechan intrusion.]

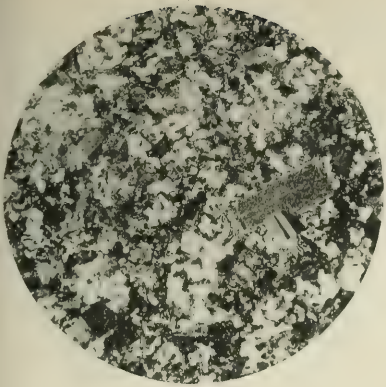


N. G. B. photo.

VIEW LOOKING EASTWARDS ACROSS LLYNAU CROGENEN TO PARED-Y-CEFN HIR.

[a = ‘China-stone’ Ashes. b = Bryn Brith. c = Pared-y-Cefn Hir. d = Hollow on granophyre outcrop.]

1.



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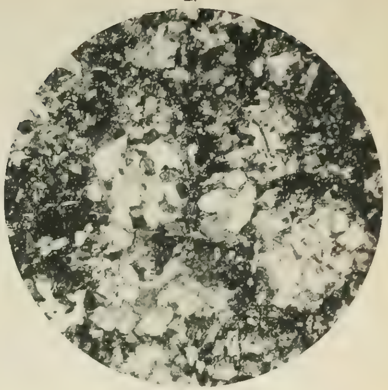

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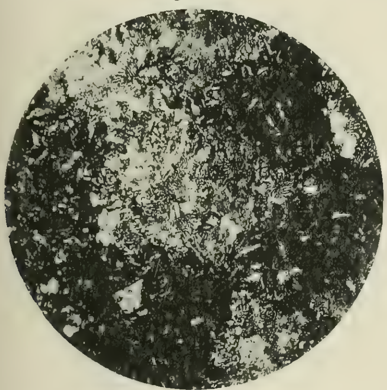

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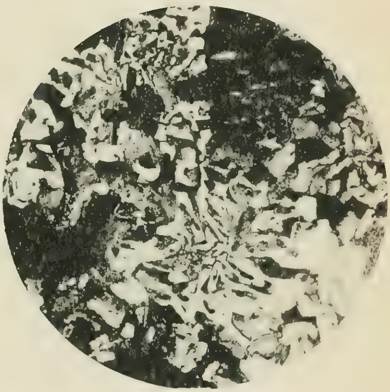

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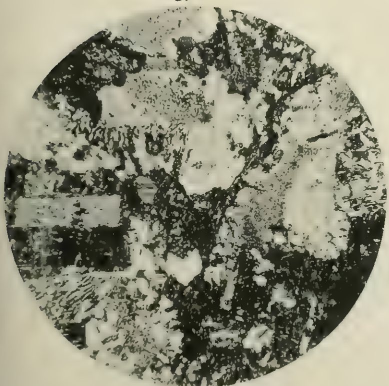

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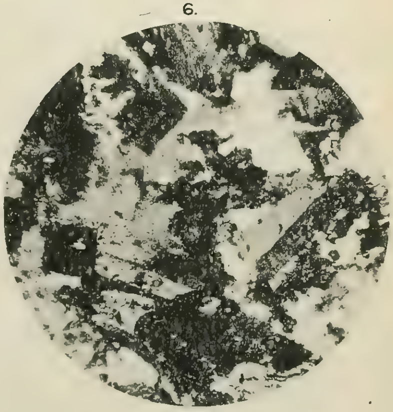

A.K.W. Photomic.

Bemrose, Collo., Derby.

INTRUSIVE ROCKS from the ARTHOG - DOLGELLEY DISTRICT.

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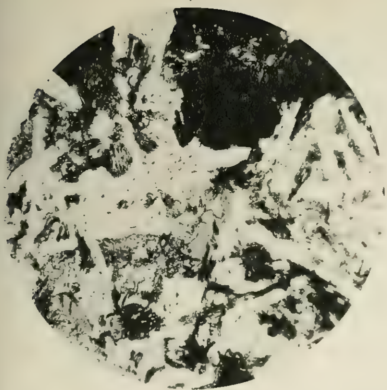

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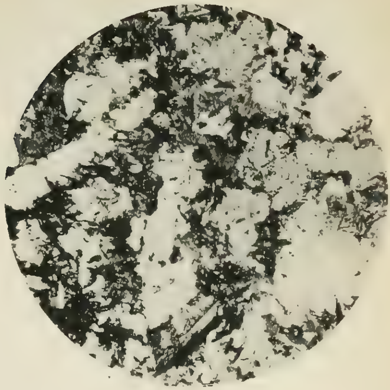

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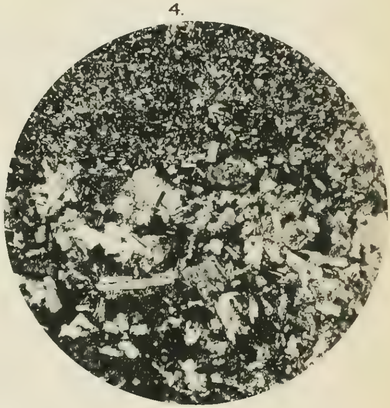

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A K.W. Photomic. Bemrose, Collo., Derby.

INTRUSIVE ROCKS from the ARTHOG-DOLGELLEY DISTRICT.

GEOLOGICAL M

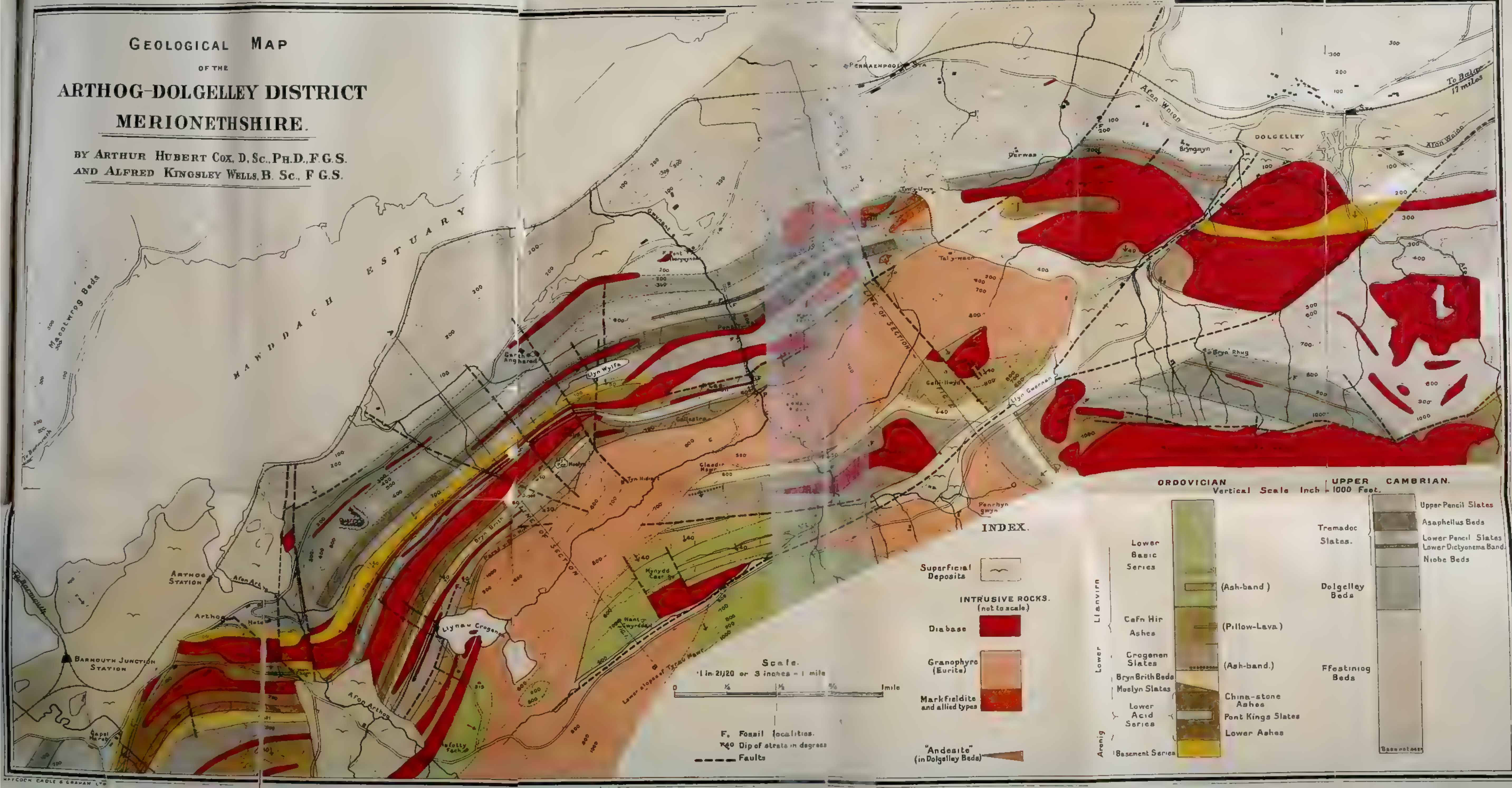
OF THE

ARTHOG-DOLGELLEY

MERIONETHSH

BY ARTHUR HUBERT COX, D. S

AND ALFRED KINGSLEY WELLS.


GEOLOGICAL MAP
OF THE
ARTHOG-DOLGELLEY DISTRICT
MERIONETHSHIRE.
BY ARTHUR HUBERT COX, D.Sc., PH.D., F.G.S.
AND ALFRED KINGSLEY WELLS, B. Sc., F.G.S.
MAWDDACH ESTUARY
DOLGELLEY
Afon Wnion
To Bala 17 miles
Llyn Wylfa
Llyn Gwernan
Llynau Cregennen
Arthog Station
Barmouth Junction Station
Afon Arthog
LINE OF SECTION
INDEX.
Superficial Deposits
INTRUSIVE ROCKS. (not to scale.)
Diabase
Granophyre (Eurite)
Markfieldite and allied types
"Andesite" (in Dolgelley Beds)
F. Fossil localities.
Dip of strata in degrees
Faults
Scale.
1 in 21,120 or 3 inches = 1 mile
0 ¼ ½ ¾ 1 mile
ORDOVICIAN
Vertical Scale 1 Inch = 1000 Feet.
UPPER CAMBRIAN.
Lower Llanvirn
Arenig
Lower Basic Series
(Ash-band.)
Cafn Hir Ashes
(Pillow-Lava.)
Cregennen Slates
(Ash-band.)
Bryn Brith Beds
Moelyn Slates
China-stone Ashes
Lower Acid Series
Pont Kings Slates
Lower Ashes
Basement Series
Tremadoc Slates.
Upper Pencil Slates
Asaphellus Beds
Lower Pencil Slates
Lower Dictyonema Band.
Niobe Beds
Dolgelley Beds
Ffestiniog Beds
MAYCOCK CADLE & GRAHAM LTD


300
300
200
100
To Bala
17 miles
STA.
Afon Wnion
100
200
700

district which would be expected to show most analogy to Cumberland: namely, North Wales, the Authors assigned a pre-Upper Bala date to intrusions, petrographically resembling those of the Lake District, invading a volcanic series of the same age as the Lake-District volcanics, and with similar structural relations, and also described faulting of Ordovician age. This early movement was considered to have acted along the same lines as the Caledonian movements; but in the Lake District a difference of 15° or 20° in orientation occurred, and the earlier movement resulted in gentle folds of large amplitude without cleavage. He would be glad to know something of the petrographical evidence for the age of the Welsh intrusions, and whether anything was known of the nature of the early movements.

Dr. J. V. Elsden said that he was in complete agreement with the previous speakers as to the importance of the Authors' work. He was particularly interested in the occurrence of allanite recorded in the paper. The common association of this mineral with epidote led him to ask the Authors whether these rocks were epidotized. The distribution of epidote in North Wales possessed considerable interest, since its occurrence in quantity seemed to be restricted to the eastern part of Carnarvonshire; and it would be useful to know whether the marked development of epidote in Snowdonia extended into the district now described by the Authors.

Prof. A. H. Cox thanked the Fellows present for the kind reception accorded to the paper, and Prof. Watts for his most flattering remarks. It was a source of great encouragement to younger workers to receive appreciation from so distinguished an authority as Prof. Watts, and from one who was so widely recognized as an expert on the Palæozoic rocks. The speaker stated that the stratigraphical sequence and structure left no room for doubt as to the existence of a second *Dictyonema* horizon. The specimens had been examined by Mr. Pringle, and they agreed closely with the species found at the lower horizon. The speaker summarized the petrographical and structural evidence that suggested an early Bala date for the intrusions, and pointed out that no acid intrusions were found above the youngest acid eruptives, and no basic intrusions above the youngest basic eruptives. The agreement between the markfieldites of the Dolgelley district and those of Charnwood Forest was exceedingly close, also that between the more basic granophyric rocks in the two areas. The speaker was much indebted to Prof. Watts for affording facilities for an examination of Charnwood slides. The uniformity of individual sills over wide areas was very striking; but there were several examples of laccolites tailing out within the district. He was much impressed by the many similarities between North Wales and the Lake District, as described in Mr. Green's various papers. The strike was regular throughout most of the district under discussion, but folds of low amplitude, which cross the general strike, appear in the south-west, and become more important in the areas

farther south. The repeating faults and some of the normal faults were later than the intrusions; others, however (not apparent in the horizontal sections displayed), were undoubtedly earlier, as portrayed on the geological map.

Mr. A. K. Wells said that the more basic rocks of the district were often epidotized. Epidote occurs abundantly as rosettes and grains in plates of chlorite, and as grains in the felspars. In one of the sketches of allanite-crystals exhibited an outgrowth of epidote from the allanite was shown.

[January 17th, 1921.]

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OF

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CONTENTS.

PAPERS READ.

[The Editor of the Quarterly Journal is directed to make it known to the Public that the Authors alone are responsible for the facts and opinions contained in their respective Papers.]

*** The Council request that all communications intended for publication by the Society shall be clearly and legibly written on one side of the paper only, with proper references, and in all respects in fit condition for being at once placed in the Printer's hands. Unless this is done, it will be in the discretion of the Officers to return the communication to the Author for revision.

The Library at the Apartments of the Society is open every Week Day from Ten o'clock until Five, except on Saturdays (when the hours are from 10 to 1), and except during the fortnight commencing on the first Monday in September, when the Library is closed for the purpose of cleaning.

Fellows are reminded that, after the completion of Vol. LXXVI (1920), they will not be entitled to receive the Quarterly Journal regularly, unless a subscription at the rate of 10*s*. per volume is paid in advance, along with their Annual Contribution to the Society. Those Fellows who do not require the complete series can obtain separate parts at the price of 3*s*. each, if applied for within one year of the date of issue.

Vol. LXXVI.
Part 4.

No. 304.

THE

QUARTERLY JOURNAL

OF THE

GEOLOGICAL SOCIETY.

EDITED BY

THE PERMANENT SECRETARY.

[With Four Plates, illustrating Mr. E. S. Cobbold's Paper.]

March 9th, 1921.

LONDON:

LONGMANS, GREEN, AND CO.

PARIS:—CHARLES KLINCKSIECK, 11 RUE DE LILLE.

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ORDINARY MEETINGS OF THE GEOLOGICAL SOCIETY TO BE HELD AT BURLINGTON HOUSE.

Session 1920–1921.

1921.

Wednesday,	March	23
,,	April	20*
,,	May	4 —25*
,,	June	8 —22*

[*Business will commence at 5.30 p.m. precisely.*]

The asterisks denote the dates on which the Council will meet.

9. *The* Cambrian Horizons *of* Comley (Shropshire) *and their* Brachiopoda, Pteropoda, Gasteropoda, *etc.* By Edgar Sterling Cobbold, F.G.S. (Read April 21st, 1920.)

[Plates XXI–XXIV.]

Contents.

I. Introduction.

The objects of this paper are to define the horizons of the Cambrian system at Comley, to describe and illustrate the species of brachiopoda, pteropoda, and gasteropoda, and to discuss the relationships of the faunas one to the other and to those of other Cambrian areas.

The majority of the specimens now described were obtained from the excavations carried out between the years 1907 and 1914, on behalf of the Committee for the Excavation of Critical Sections in Palæozoic Rocks, appointed by the British Association for the Advancement of Science. Some specimens were collected in 1892 for H.M. Geological Survey by Mr. J. Rhodes, and others have been obtained by myself or other observers at various dates since 1890.

II. The Comley Horizons.

Details of the sections opened by excavation have been given in the reports of the meetings of the British Association held at Dublin in 1908, Winnipeg in 1909, Sheffield in 1910, Portsmouth in 1911, Dundee in 1912, and Manchester in 1915.

In Table I (facing p. 326) the various horizons from which different assemblages of fossils have been obtained are set out in descending order, with the proposed nomenclature in spaced type, followed by index-letters, thicknesses, general lithological characters, and suggested correlations. The designations used by me in previous communications and in my reports to the British Association are inserted in ordinary type in the first column. Since these

differ considerably from those now proposed, a few words of explanation seem to be necessary.

As the study of the fossils collected from the different beds proceeded, it became apparent that they might prove to be of more than local interest, and it was therefore desirable that the original indefinite or cumbersome terms, based on local names, or lithological variations, should be abandoned in favour of others based upon the fossil contents. It was also evident that, in several instances, beds or groups of beds, to which a local name had been allotted, contained more than one set of fossil forms, and it seemed undesirable to resort to any extended use of such terms as Upper, Middle, Lower, etc.

Thus the 'Lower Comley Sandstone' has been divided into five parts, and the three divisions previously called 'The Grey Limestones,' 'The Black Limestone,' and 'The Shoot-Rough Road Flags,' into two horizons in each case.

III. Classification, Terminology, and References.

The classification and terminology used in the descriptions of the brachiopoda follow closely those adopted by Dr. C. D. Walcott. In view of the very full references given by him, it has not been considered necessary to quote more than (1) the work in which any species was first described, (2) the pages, plates, and figures in his monograph, and (3) any references to works later than those to which he had access.

In order to avoid repetition, works enumerated in footnotes are designated by the names of the authors and dates. The full references may be found by referring to the Bibliography.

I have followed the usual practice in including such tubular fossils as *Hyolithellus*, *Helenia*, etc. among the Pteropoda, but am doubtful whether they really belong to that order.

IV. Bibliography.

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E. Billings. 1872.—Can. Nat. n. ser. vol. vi, pp. 465–80. 'On some Fossils from the Primordial Rocks of Newfoundland.'

C. Callaway. 1874.—Q. J. G. S. vol. xxx, p. 196. 'On the Occurrence of a Tremadoc Area near the Wrekin in South Shropshire.'

C. Callaway. 1877.—*Ibid.* vol. xxxiii, pp. 652–72. 'On a New Area of Upper Cambrian Rocks in South Shropshire.'

C. Callaway. 1878.—*Ibid.* vol. xxxiv, pp. 754–63. 'Quartzites of Shropshire.'

E. S. Cobbold. 1909.—Rep. Brit. Assoc. 1908, Dublin, pp. 231–42. 'Report on some Excavations in the Cambrian Rocks of Comley (Shropshire).'

E. S. Cobbold. 1910 *a*.—*Ibid.* 1909, Winnipeg, pp. 181–86. 'Report on some further Excavations among the Cambrian Rocks of Comley (Shropshire).'

E. S. Cobbold. 1910 *b*.—Q. J. G. S. vol. lxvi, pp. 19–51. 'On Trilobites from the Cambrian Rocks of Comley.'

E. S. Cobbold. 1911 *a*.—Rep. Brit. Assoc. 1910, Sheffield, pp. 113–22. 'Third Report on Excavations among the Cambrian Rocks of Comley.'

E. S. Cobbold. 1911 *b*.—Q. J. G. S. vol. lxvii, pp. 282–311. 'Trilobites from the *Paradoxides* Beds of Comley.'

E. S. Cobbold. 1912.—Rep. Brit. Assoc. 1911, Portsmouth, pp. 111–15. 'Fourth Report on Excavations among the Cambrian Rocks of Comley.'

[To face p. 326.

TABLE I.—THE COMLEY

Index-letters.	*Estimated or observed thicknesses in feet.*	*Genera*	*equivalents in America.*
Cx	?	Soft blue-	
Ca	? 500	Micaceous or calcar	
Bc	5	Fine and c and shal	a.
Bb_5	18	Coarse gri bed at t	Wales.
Bb_4	?	Green anc calcareo	
Bb_3	?	?	
Bb_2	? 300	Micaceous sional b	uneaton.
Bb_1	5 to 38	Coarse con of fragm	
l beds from Ab_5 to Ba_3.			
Ba_3	4+	Phosphati	
Ba_2	300	Fine blue bands or	
Ba_1	25	Hard, ring conglom deposit a	
to beds Ab_4 below.			
Ad	0·5	Calcareous material	
Ac_5	0·5	Black to p tic limes	*Protolenus* Zone, New Brunswick.
Ac_4	0·75	Grey to re with pho	North Attleboro' Beds, Massachusetts; *Callavia* Beds, Manuel's Brook (Newfoundland).
Ac_3	1·75	Grey and p much ph	
Ac_2	2·5	Red or pu dular.	
Ac_1	?	Bright gre	
Ab_4	450	Green sanc reous bec	
Ab_3		Green anc calcareou	
Ab_2		Muddy sa beds.	
Ab_1	27	Greenish-g conglom	
Aa	22	Yellow sa down in which be base.	

TABLE I.—THE COMLEY CAMBRIAN HORIZONS.

	Local or lithological names used by the Author in previous publications.	Proposed names for the faunal horizons.	Index-letters.	Estimated or observed thicknesses in feet.	General lithological characters.	Approximate equivalents in Europe.	Approximate equivalents in America.
	Shoot-Rough Wood Shale.	....	Cx	?	Soft blue-grey shales.	Shineton Shales, Shropshire. Tremadoc, North Wales.	
	Shoot-Rough Road Shale.	*Orusia* Shales.	Ca	? 500	Micaceous shale, with thin mudstone or calcareous courses.	*Orusia-lenticularis* Beds, Scandinavia. *Orusia-lenticularis* Beds, North Wales.	
The Comley Sandstone. Upper Division.	Shoot-Rough Road Flags.	*Billingsella* Beds.	Bc	5	Fine and coarse grits, with calcareous and shaly beds.	*Paradoxides-forchammeri* Zone, Scandinavia.	
		Paradoxides-davidis Flags.	Bb_5	18	Coarse gritty flags, with a calcareous bed at the summit.	*Paradoxides-davidis* Beds, Scandinavia. *Paradoxides-davidis* Beds, North & South Wales. Upper *Davidis* Fauna, Nuneaton.	
	Shoot-Rough Road Sandstone.	*Paradoxides-rugulosus* Sandstone.	Bb_4	?	Green and brown sandstone, with a calcareous bed at the summit.	Lower *Davidis* Fauna, Nuneaton.	
	Unexplored interval.		Bb_3	?	?	? *Hartshillia* Fauna, Nuneaton.	
	Hill-House Shale.		Bb_2	? 300	Micaceous flaggy shales, with occasional beds of grit.	*Paradoxides-hicksi* Zone, South Wales & Nuneaton. *Paradoxides-hicksi* Zone, Scandinavia.	
	Hill-House Grits. The Comley Breccia-Bed.	*Paradoxides-intermedius* Grits.	Bb_1	5 to 38	Coarse conglomeratic grits and breccia of fragments from Ac_2 & Ac_1 below.		
	Non-sequence, with overlap on to all beds from Ab_5 to Ba_3.						
	Hill-House Flags.	*Dorypyge-lakei* Flags.	Ba_3	4+	Phosphatic gritty flags.	*Paradoxides-œlandicus* Zone, Scandinavia. Purley Shales (*pars*), Nuneaton.	
	Quarry-Ridge Shales.	....	Ba_2	300	Fine blue and brown shales, with bands or beds of hard, ringing grit.		
	Quarry-Ridge Grit.	*Paradoxides-groomi* Grits.	Ba_1	25	Hard, ringing, glauconitic grit, with conglomerate and a thin phosphatic deposit at the base.		
	Unconformity, with erosion down to beds Ab_1 below.						
The Comley Sandstone. Lower Division.	The Black Limestone.	*Lapworthella* Limestone.	Ad	0·5	Calcareous and phosphatic granular material.		
		Protolenus Limestone.	Ac_5	0·5	Black to pale-grey, compact, phosphatic limestone.	? Purley Shales (*pars*), Nuneaton.	*Protolenus* Zone, New Brunswick.
	The Grey Limestones.	*Strenuella* Limestone.	Ac_4	0·75	Grey to red-purple gritty limestone, with phosphatic inclusions.		North Attleboro' Beds, Massachusetts; *Callavia* Beds, Manuel's Brook (Newfoundland).
		Microdiscus-bellimarginatus Limestone.	Ac_3	1·75	Grey and pinkish-grey limestone, with much phosphate in places.		
	The *Olenellus* Limestone.	*Olenellus* Limestone.	Ac_2	2·5	Red or purple sandy limestone, nodular.	Camp-Hill Quartzite, Nuneaton.	
	Lower Comley Sandstone.	*Callavia* Sandstone.	Ac_1	?	Bright green sandstone.		
		....	Ab_4	450	Green sandstone, with nodular calcareous beds.		
		Holmia Sandstone.	Ab_3		Green and reddish sandstone, with calcareous beds.		
		....	Ab_2		Muddy sandstone with some flaggy beds.	Hollybush Sandstone, Malvern.	
		Obolella-groomi Beds.	Ab_1	27	Greenish-grey sandstone and mottled conglomeratic beds below.	Tuttle-Hill Quartzite, Nuneaton (after Lapworth).	
	The Wrekin Quartzite.	The Wrekin Quartzite.	Aa	23	Yellow sandy quartzite, graduating down into compact blue quartzite which becomes conglomeratic at the base.	Malvern Quartzite, Malvern Hills. Park-Hill Quartzite, Nuneaton (after Lapworth).	

E. S. Cobbold. 1913 *a*.—Rep. Brit. Assoc., 1912, Dundee, pp. 136–43. 'Fifth Report on Excavations among the Cambrian Rocks of Comley.'

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V. THE COMLEY BRACHIOPODA.

The species hitherto collected from Comley are placed under the following families and genera:—

PATERINIDÆ Schuchert.

MICROMITRA (Meek) Walcott, 1912.

MICROMITRA sp. indet. (Pl. XXI, figs. 18 & 19.)

Cf. *Kutorgina cingulata* Billings, var. *pusilla* Linnarsson, 1876, p. 25 & pl. iv, figs. 53–54.

Cf. *Micromitra pusilla* Linnarsson, Walcott, 1912, p. 339 & pl. iii, figs. 2, 2*a–c*.

Two specimens [2133, 2134] [1] indicate the presence of a form allied to that described by Linnarsson from the *Paradoxides-forchammeri* Zone of Scandinavia. They are not sufficiently well-preserved to be identified with certainty.

A ventral valve is semicircular in outline, and has the apex recurved to a point beyond the posterior margin. The shell is corneous, dark, and shows radiating riblets crossed by very fine, impressed, concentric striæ, which strengthen in places to concentric rugosities.

Dimensions.—Length = 2 mm.; width at about the half length = 2·5 mm.; height = 1 mm.

Locality and horizon.—Comley, Middle Cambrian; from the *Billingsella* Beds, horizon Bc.

Sub-genus **Paterina**.

MICROMITRA (PATERINA) PHILLIPSI Holl. (Pl. XXI, figs. 1–3.)

Obolella phillipsii Holl, 1865, Q. J. G. S. vol. xxi, p. 102, figs. 10 *a*–10 *c*.
Obobella (?) phillipsi (Holl), Davidson, 1866, Pal. Soc. Monogr., Brit. Foss. Brach. vol. iii, part 7, No. 1, p. 62 & pl. iv, figs. 17 *a*–19.
Kutorgina cingulata Davidson, 1871, Pal. Soc. Monogr., Brit. Foss. Brach. vol. iii, pt. 7, No. 4, p. 342 & pl. l, fig. 25.
Micromitra (*Paterina*) *phillipsi* (Holl), Walcott, 1912, U.S. Geol. Surv. Monogr. vol. li, p. 351 & pl. iii, fig. 8.

Through the kindness of Prof. Sollas it has been possible to compare the Comley specimens with those in the University Museum, Oxford (Holl & Groom collections). There can be no doubt as to the reference of the Comley specimens to Holl's species. The forms of the tests and their method of preservation are identical, but there are some points in which the Comley shells exhibit features not seen in the specimens from Malvern at Oxford.

(1) The external surface often, but not always, shows traces of radiating raised lines, as well as the lines of growth; but the two characteristics occupy different parts of the shell, and have not been seen to cross one another as they do in *M. sculptilis* Meek [2] (fig. 1).
(2) The line of flexure between the lateral slopes and the false area is well rounded, not a sharp angle.
(3) The false area is almost vertical; the triangular pseudodeltidium is wide; the angle at its apex (fig. 2, posterior view) is about 120°; it is convex, and extends some distance down towards the posterior margin.
(4) A well-preserved interior, referred to the ventral valve [2335], with the corresponding internal cast [2334] (fig. 3) exhibits numerous radiating shallow channels, and also under the umbo three comparatively strong ridges, one in an axial position, the others making with it an angle of about 10° on each side.

The shells are widest at about a quarter of the length from the posterior margin.

[1] The numbers in square brackets are those attached to the specimens in my collection, unless otherwise stated.
[2] C. D. Walcott, 1912, p. 335, & pl. iii, figs. 5 & 5 *a*–5 *c*.

The lengths of the Comley specimens range from 4 to 5 millimetres, the ratio of length to width is about 1 to 1·3, and that of length to height about 1 to ·33.

Several of the best-preserved specimens are in the collection made by Mr. Rhodes for H.M. Geological Survey.

Locality and horizon.—Lower Cambrian. The Cwms sub-area of Comley and also west of Comley Quarry; from the *Obolella-groomi* Beds, horizon Ab_1.

MICROMITRA (PATERINA) RHODESI, sp. nov. (Pl. XXI, figs. 4 *a*–4 *c*, 5, 6, & ? 9.)

Type-specimen [RR 1473], Geological Survey collection.

Diagnosis.—Ventral valve: outline nearly semicircular, with lateral angles sharp, and inclined to be alate; greatest width at the posterior margin; convexity moderate, anterior and lateral slopes straight; apex marginal, pointed and somewhat erect; false area inclined a little forwards; pseudodeltidium triangular, gently convex, wide, angle made by its bounding sides about 120°, marked by two pairs of radiating angular lines so as to be polygonal in horizontal section; line of flexure from lateral slopes of shell to false area very abrupt and transverse to the axial line; free posterior margin of pseudodeltidium arched upwards; shell-substance corneous and very thick, built up of many laminæ; surface marked by irregular concentric ridges which pass round the lateral angles to the false area, and are traceable across the pseudodeltidium.

Remarks.—There are a few radiating ridges on the central part of the test in one specimen [RR 1476]. Several specimens have the surface adventitiously indented in many places.

Dimensions in millimetres:—

	[RR 1473]	[RR 1470]	[RR 1471]
Length	?	6·0	5·5
Width	8·75	9·25	8·0
Height	1·6	1·4	1·4

The species is chiefly distinguished by its abrupt flexure-line, its polygonal pseudodeltidium (fig. 4 *b*), and by being widest at the posterior border.

For comparison with other species, see p. 331.

Locality and horizon.—Comley, Lower Cambrian; from the mottled (conglomeratic) and greenish-grey beds of the Road Quarry in the Cwms sub-area, horizon Ab_1.

Dorsal valve (fig. 9). The exfoliated test [RR 1465] has a very prominent vertical apex, and is regarded as a dorsal valve. It is found on the same piece of rock with an external cast referred to *M. phillipsi*, and may belong to that species; but its general outline is more suggestive of *M. rhodesi*.

MICROMITRA (PATERINA) KINGI, sp. nov. (Pl. XXI, figs. 7 & 8 *a*–8 *b*.)

Type-specimen [King 2], Geological Survey collection.

Diagnosis.—Ventral valve: outline posteriorly somewhat hexagonal, but anteriorly semicircular; length and width equal; widest at about the half-length, posterior border about two-thirds the greatest width, lateral angles well-marked but not sharp; rather strongly convex; false area slightly inclined forwards, pseudodeltidium triangular, convex, of moderate width, angle made by its bounding lines about 90°; shell-substance corneous, not very thick; exterior marked with concentric ridges, which are irregular and in places present a beaded appearance.

Internally, or on an interior layer, there are numerous radiating striæ.

Remarks.—The concentric ridges appear to be rather coarser in this species than in the two previously noticed, but are only known from the marginal portions of the shell.

Dimensions in millimetres:—

	[King 2 *h*]	[King 2 *g*]
Length	5·75	?
Width	6·75	7·5
Width at posterior border	5·0	5·0
Height	2·0	?

The species is distinguished by its short posterior border, by its pseudodeltidium being nearly a right-angled triangle, and by the forward inclination of the false area.

Locality and horizon.—The Cwms sub-area of Comley, Lower Cambrian; from the *Obolella-groomi* Beds, horizon Ab_1.

These three species of *Micromitra* appear to be closely related. They occur together in the same beds, but in different numerical proportions. *M. kingi* has been found only in the mottled beds, *M. phillipsi* in the same beds and sparingly in the greenish-grey sandstones, *M. rhodesi* sparingly in the mottled beds and fairly abundantly in the greenish-grey sandstones.

They are clearly distinguished one from the other by their outlines and false areas. The surface-characters seem to differ a little in detail.

The divergences may be tabulated as follows:—

	M. kingi.	*M. phillipsi.*	*M. rhodesi.*
Apex	(Not known.)	Projecting backwards.	Approximately vertical.
Anterior slope.	Decidedly convex.	Slightly convex.	Straight.
False area	Inclined forwards.	Vertical.	Inclined forwards.
Angle at apex of pseudodeltidium	about 90°.	about 120°.	about 120°.
Greatest width.	At half-length.	At quarter-length.	At posterior margin.
Postero-lateral angles.	Blunt.	Rounded.	Sharp.
Shell-substance.	Moderately thick.	Rather thick.	Very thick.

Micromitra (Paterina) labradorica (Billings). (Pl. XXI, figs. 10 *a*–13.)

Obolus labradoricus Billings, 1861, Geol. Surv. Canada, Pal. Foss. vol. i, p. 6, fig. 6.
Micromitra (*P.*) *labradorica* Billings, Walcott, 1912, p. 347 & pl. ii, figs. 2, 2 *a*–2 *f*.
(?) *Kutorgina cingulata* Billings, Callaway, 1878, Q. J. G. S. vol. xxxiv, p. 759.
(?) Do. do. do. Lapworth, 1888, Geol. Mag. p. 485.
(?) Do. do. do. Lapworth, 1891, *Ibid.* p. 532.
(?) *Kutorgina cingulata* Billings, Lapworth & Watts, 1894, Proc. Geol. Assoc. vol. xiii, p. 310.
Kutorgina and *Kutorgina cingulata* Cobbold, Brit. Assoc. Rep. 1909, p. 182; 1910 *a*, p. 118; 1912, pp. 138, 140, 141.

It seems probable that the specimens from Comley which have previously been referred to *K. cingulata* belong in reality to Billings's second species, now included by Dr. Walcott under the genus *Micromitra*, sub-genus *Paterina*.

The Comley specimens usually have a black outer surface: that is, covered with rounded concentric ridges, spaced, in the anterior part of the valves, at from 4 to 8 to the millimetre. Where exfoliation has taken place the internal laminæ of shell are marked by radiating folds, which extend to distances that vary with the degrees of exfoliation.

Two specimens are known in which the dorsal and ventral valves are united. One of these [B 40306] in the British Museum (figs. 10 *a*–10 *c*) is now much damaged, and it is impossible to ascertain whether the apex is as much curved down at the back as is represented in the side view, the sketches for which were made before the other specimens were studied. It had the two valves slightly displaced one upon the other. In the other specimen, [730] in the collection for the British Association, the shells are somewhat crushed together, and they have suffered much from weathering.

The dimensions of five dorsal and three ventral valves are as follows, in millimetres:—

	Dorsal Valves.					*Ventral Valves.*		
Nos. on specimens	[B 40306]	[730]	[2188]	[2179]	[1519]	[B40306]	[730]	[729]
Length	4·5	about 9	4·5	6·0	4·2	5·0	9·5	7
Width..............	6·5	about 10	7·5	8·5	5·7	6·5	11·0	10
Height	0·7	1·4	1·0	2·5	1·5	1·3	1·6	2

The concentric ridges of the exterior surface can often be traced round the postero-lateral angles of the shell on to the false area. In the dorsal valves the central part of the false area appears to have been widely open, no trace of a pseudochilidium having been detected. In the ventral valves the pseudodeltidium is occasionally seen, and takes the form of a very small, horizontal, semicircular shelf (fig. 13).

Through the kindness of Dr. Walcott, I have had an opportunity of examining several specimens of the species from Bic, Quebec. The only difference that has been detected is that the concentric ridges in the Canadian specimens are rather smaller and more numerous than those on shells from Comley of the same size.

Locality and horizons.—Comley, Lower Cambrian; from the *Callavia* Sandstone, *Olenellus* Limestone, *Microdiscus-bellimarginatus* Limestone, and *Protolenus* Limestone: horizons Ac_1, Ac_2, Ac_3, & Ac_5.

MICROMITRA (PATERINA) MINOR, sp. nov. (Pl. XXI, figs. 14–16.)

(?) Iphidea bella Billings, Lapworth, 1888, Geol. Mag. p. 485.
Iphidea (?) Cobbold, 1911, Rep. Brit. Assoc. (1910, Sheffield), p. 298.

A form of the genus that is much smaller and more convex than *M.* (*P.*) *labradorica*, is found associated with it in the *Olenellus* Limestone of Comley.

Type-specimen [755].

Diagnosis.—Ventral valve: outline subquadrate, wider than long, lateral angles slightly rounded; convexity strong, anterior and lateral slopes gently convex; apex fairly sharp, a little incurved, and overhanging the posterior border; shell-substance corneous, exfoliating in layers which mark stages of growth; surface marked with rounded concentric ridges usually very regularly disposed, but sometimes two or more appear to coalesce so as to form one ridge; they are continuous round the lateral angles on to the false area; false area with a wide, open delthyrium (fig. 14); pseudodeltidium either not present at all, or represented only by a minute projection under the apex, which has the appearance of being the posterior margin of the umbonal shield. Internal markings very minute. Three specimens, a little exfoliated at the apex, exhibit a more or less flattened space under the umbo; on the anterior slopes are traces of radiating corrugations, and also two rather stronger ridges that are slightly sinuous and divergent; in one of the specimens [750] (figs. 16 *a*–16 *c*) a slightly-elongated central prominence on the cast may be compared with the 'apical slit' mentioned by Dr. Walcott (1912), pp. 334, 335, 345.

Dorsal valve, not identified.

Dimensions.—Four ventral valves have the following measurements, in millimetres.

	[750]	[755]	[858]	[2178]
Length	1·25	2·0	2·1	1·5
Width.........................	1·75	2·7	3·25	2·0
Height	0·5	1·0	1·1	0·6

Comparisons with other species.—*M.* (*P.*) *minor* suggests *M.* (*P.*) *bella*[1] (olim *Iphidea bella* Billings) at first sight; but the absence of any well-marked pseudodeltidium at once precludes this reference.

[1] C. D. Walcott, 1912, pl. ii, figs. 1 & 1 *a*.

A comparison may be made with *M. (P.) logani* Walcott,[1] which has a wide, open delthyrium and a small 'shelf-like' pseudo-deltidium, but differs in form from the Comley fossil.

M. (P.) stuarti Walcott[2] has an open delthyrium, but differs in outline and convexity from *M. (P.) minor*.

The Comley form has the same general outline as *M. (P.) undosa* Moberg,[3] from drift blocks of Lower Cambrian Sandstone of Öland, but is much smaller, and the false areas cannot be compared, as the Swedish specimens are defective.

Micromitra minor, var. gibbosa nov. (Pl. XXI, fig 17.)

A specimen in the collection made by Mr. Rhodes [RR 1117], and another in the British Association collection [2178] differ from those described above in having the anterior slope much more strongly convex; this gives a gibbous aspect to the shell.

Mr. Rhodes's specimen was obtained from the *Olenellus* Limestone of Comley Quarry; the exact horizon of the other specimen is, however, doubtful.

Localities and horizon.—Comley, Lower Cambrian; from the *Olenellus* Limestone of the Quarry, horizon Ac_2. Also from the same horizon in the Cwms, about 2 miles south of Comley Quarry.

Micromitra (?) sp. indet. (Pl. XXI, fig. 26.)

Associated with *M. (P.) phillipsi* and *Walcottina* two valves have been found, which were thought to be dorsal valves of *W. lapworthi* (see below, p. 336), and were figured for description. One of the figures is reproduced in Pl. XXI. There is a strong superficial resemblance to the figures given by Walcott[4] of the dorsal valve of *Kutorgina granulata* Matthew, but the shells do not agree with the description. The umbo is not 'depressed to the cardinal line,' it stands up almost vertically, and there is no sign of 'a median septum.'

In the specimen figured the posterior portion is imperfect, but suggests a similarity to the false area of the ventral valves of *M. (P.) phillipsi* and its congeners.

Dimensions in millimetres.—Length = 9; width = 12; height = 1 or more.

Locality and horizon.—Comley, Lower Cambrian; from the Cwms sub-area, horizon Ab_1.

Walcottina, gen. nov.

Two species of brachiopoda from the lowest fossiliferous horizon known in the Comley district appear to be intermediate between

[1] 1912, pl. ii, figs. 6, 6 *a* & 6 *b*.
[2] *Ibid.* p. 354 & text-figs. A, A′, A″, B, B′.
[3] 1892, p. 112 & pl. iii, figs. 10–12.
[4] 1912, pl. v, figs. 5 *b* & 5 *c*.

the genera *Mickwitzia* and *Kutorgina*, to neither of which can they be referred without an extension of one or other of the generic diagnoses given by Dr. Walcott.[1] It is, therefore, necessary to propose a new generic name, and it seems appropriate to dedicate the genus to one who has done so much to aid the study of the Cambrian faunas in general and the brachiopoda in particular.

In common with the two above-named genera, *Walcottina* has the ventral valve considerably elevated, while the dorsal, so far as known, is comparatively flat; the pedicle-opening is a gaping orifice between the valves; and the shell-substance is made up of two or three principal layers.

The characters in which the three genera are divergent, so far as can be determined from the specimens of the new genus that are available, are as follows:—

	Mickwitzia.	*Walcottina.*	*Kutorgina.*
(1) Shell-substance ...	phosphatic.	calcareo-corneous.	calcareous.
(2) Exterior sculpture	papillose.	concentric striæ with flat bands.	concentric striæ, imbricated.
(3) Exterior surface of interior layer	radiate and concentric ridgelets.	radiate corrugations.	fine radiating lines and punctæ.
(4) Innermost surface	punctate.	smooth.	?
Ventral valve.			
(5) False area	obscurely developed.	not marked off from remainder of shell.	distinct, but short and rudimentary.

No specimens of *Walcottina* have been found that are not more or less in a decomposed condition, and consequently the exact nature of the shell-substance cannot be ascertained. They occur in a somewhat friable conglomerate from which all, or almost all, the calcareous cement has been dissolved away, and with it, presumably, any calcareous material that the shells may have contained. The matter now representing the test, though soft, is often well preserved, its surface-characters can be made out with certainty, and the component layers are usually distinctly observable. They have a corneous aspect, but may have been originally calcareo-corneous. In this respect the specimens approach *Mickwitzia*, but the exterior sculpture and that of the interior layer are more reminiscent of *Kutorgina*.

The false area in *Walcottina* is non-existent, in *Mickwitzia* it 'may or may not be obscurely defined,'[2] in *Kutorgina* it is quite distinct, judging by the figures given by Walcott.[3] In this respect the proposed genus seems to be more primitive than the other genera and to be on a par with *Rustella*.[4]

[1] 1912, pp. 329 & 579.
[2] C. D. Walcott, 1912, p. 329.
[3] *Ibid.* pl. v, figs. 1 *k* & 1 *n*.
[4] C. D. Walcott, *op. supra cit.* p. 327 & pl. i, figs. 1, 1 *a*–1 *e*.

Provisional diagnosis.—General outline either transverse or elongate oval. Ventral valve convex, with apex recurved over or beyond the posterior margin; anterior slope convex, with gently-lessening curvature, lateral slopes rather flatter; lateral angles rounded; posterior slope continuous with the lateral, without any defined false area; pedicle-opening indicated by an arching upwards of the posterior margin; shell-substance corneous or calcareo-corneous, consisting of three principal layers, of which the exterior is marked by numerous concentric impressed striæ with flat bands between them, the intermediate layer is marked by impressed lines radiating from the apex, and, towards the margins, by impressions of the concentric bands of the exterior, while the innermost layer is smooth so far as known.

Dorsal valve, not known with certainty.

Type species—*Walcottina lapworthi*, sp. nov.

Horizon—Lower Cambrian of the Comley district, Shropshire.

Walcottina lapworthi, sp. nov. (Pl. XXI, figs. 23 *a*–23 *c*, 24 *a*–24 *b*, & 25.)

Cobbold, 1916. Rep. Brit. Assoc. 1915 (Manchester), p. 118, 'brachiopod allied to both *Mickwitzia* and *Kutorgina*.'

Type-specimens [King 1 *a* & 1 *b*] in the Geological Survey collection.

Diagnosis.—Ventral valve: outline transversely oval, lateral angles rounded, posterior margin nearly straight and transverse to the axial line for about three-fifths of the width; convexity well marked; apex somewhat recurved and extending well behind the posterior margin; anterior slope of fairly even curvature, though a little flatter towards the front margin; lateral slopes tending to flatness towards the lateral angles; false area and pseudodeltidium not developed; shell-substance corneous, composed of two principal layers of moderate thickness, and an inner one which appears to be very thin; exterior marked by concentric, impressed lines, spaced fairly regularly at 7 or 8 to the millimetre, the interspaces being of the nature of flat bands, stages of growth indicated by an occasional strengthening of the concentric lines; interior layer of shell marked by many gentle corrugations radiately arranged, and dying away towards the half-length of the shell; third and innermost layer smooth, so far as seen.

A comparison between the external view (fig. 23) and that of the interior layer (fig. 24) shows that the outer layer of shell was thickened round the base of the apical portion, so that the apex in the latter figure is more acuminate than it is in the former.

Dorsal valve, not known.

The type-specimens were collected by Mr. W. Wickham King, and presented by him to the collection which was being made in 1892 by Mr. J. Rhodes.

The species is dedicated to Prof. C. Lapworth, who suggested a reference to *Mickwitzia* in the field at the time when the specimens were found.

Dimensions of type-specimens.—Lengths = 5 and 7·5 mm.; widths = 7·1 and 9·25 mm.; heights = 2 and 2·5 mm.

Locality and horizon.—The Cwms sub-area of Comley; from the conglomeratic beds at the base of the *Obolella-groomi* Beds, horizon Ab_1.

WALCOTTINA ELEVATA, sp. nov. (Pl. XXI, figs. 20 *a–e*, & 22.)

Cobbold, 1916. Rep. Brit. Assoc. 1915 (Manchester), p. 118, 'brachiopod allied to both *Mickwitzia* and *Kutorgina*.'

The type-specimens consist of an exfoliated fragment [1914] disclosing about half of a ventral valve and its counterpart [1916]. Another specimen [2282], a sandy internal cast of a complete shell in rotten stone, is used to supplement the description.

Diagnosis.—Ventral valve: general form elevated; outline an elongate oval, slightly flattened at the posterior margin, length rather greater than width; lateral angles well rounded; convexity high, highest point situated at about a quarter of the length from the apex; apex recurved, and projecting but little beyond the posterior margin; shell-substance corneous, and composed of three principal layers, marked as in *W. lapworthi*, except that the radiating corrugations of the inner layer do not extend so far forwards, and that traces of the external concentric bands are seen upon the interior layer near the anterior margin; pedicle-opening represented by an upward arching of the posterior margin (see Pl. XXI, fig. 22).

Dimensions of the type-specimen [1914].—Length = 4 mm., width = 4 mm., height = 3·75 mm.; and of specimen [2282], length = 7 mm., width = 6·9 mm., height = 4·5 mm.

Dorsal valve (?). Associated on the same little piece of rock with the type-specimen are two shells which from their general form are regarded as dorsal valves, but the surfaces are not sufficiently well preserved to prove that the sculpture was similar to that above described for the ventral valve.

The outline is that of a sector of a circle greater than a semicircle, the two radii forming a notched posterior margin; the apex projects prominently upwards; the anterior and lateral slopes fall steeply from it, then become horizontal or even concave, and finally fall again to the margin; the posterior angles are rounded; the surfaces show concentric lineation, and the dimensions are such as to correspond with those of the type-specimen.

Observations.—The attenuation of the apex of the ventral valve (fig. 20 *a*) [1914] suggests a possible pedicle-tube, especially when compared with figs. 20 *b* & 20 *c*, which represent the exterior of the same individual, but the former is a representation of the interior layer of shell, not an internal cast. The exterior layer of shell was evidently considerably thickened at the apical part of the valve. The arching upwards of the posterior margin shown in fig. 22 [2282] indicates the more probable position of the pedicle-opening.

This species is distinguished from *Walcottina lapworthi* by the

greater elevation of the ventral valve, and by being slightly elongate instead of decidedly transverse.

Locality and horizon.—The Cwms sub-area of Comley, Lower Cambrian; from the *Obolella-groomi* Beds, horizon Ab_1.

OBOLIDÆ King.

Obolus Eichwald.

Obolus parvulus, sp. nov. (Pl. XXII, figs. 13–19.)

Type-specimen [1512 *a*].

Diagnosis.—General form ovate, bluntly acuminate, apices marginal; dorsal valve, length and width sub-equal; ventral valve longer than wide; convexity moderate, about a sixth of the width; shell, apparently calcareo-corneous, consisting of two principal layers, weathering white or bluish white; exterior with from three to six well-defined lines of growth, numerous faint concentric striæ and occasional traces of radiating lines, in the dorsal valve there is an incised mesial line; interior of ventral valve showing the pedicle-groove and, continuous with it (though marked off by a transverse line) the concave visceral area, on each side of which are traces of the main vascular sinuses: interior of dorsal valve showing a narrow but well-marked mesial ridge, which near the middle of the valve gives off outward curving branches on either side, the mesial ridge widens out posteriorly and, in the casts, is lost in the impression of the area.

Dimensions.—Nineteen valves measured from ·9 to 2·35 millimetres in length; the average proportion of length to width in ventral valves is 1 to ·8, in dorsal valves 1 to ·9.

The ventral valve of *O. parvulus* is very like *O. parvus* Walcott [1] from the Lower Cambrian of the Rocky Mountain province.

The dorsal valve of the Comley species differs in being longer than wide, and the mesial depression is much narrower than that shown in Walcott's figure.

The surface-character of *O. parvus*, said to be like that of *Lingulella (Lingulepis) longinervis* Matthew [(?) a clerical error for *L. (L.) gregwa* Matthew] has not been observed in *O. parvulus*.

Locality and horizon.—Comley, Lower Cambrian; from the *Olenellus* Limestone, Horizon Ac_1, the *Microdiscus-bellimarginatus* Limestone Ac_2, and the *Protolenus* Limestone Ac_5.

Obolus (?) linnarssoni, sp. nov. (Pl. XXII, figs. 23–25.)

Obolus (?) sp. indet., Linnarsson, 1876, Bihang K. Svensk. Akad. Handl. vol. iii, No. 12, p. 16 & pl. iii, fig. 31.
(?) Lingulella sp. indet., Matley, 1911, Q. J. G. S. vol. lxvii, p. 301 & pl. xxvi, fig. 7.
Obolus sp. indet. *g*, Walcott, 1912, Monogr. U.S. Geol. Surv. vol. li, p. 423.

Linnarsson's description is as follows:—

'The shell is very slightly convex; its circumference resembles a sector of

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[1] 1912, p. 408, text-figs. 37 A & 37 B.

a circle; the front is broadly rounded, the slopes forming the beak seem to be nearly straight, and make a somewhat obtuse angle. The surface is not well preserved in any specimen; judging, however, from some small fragments, I should think that a concentric striation is prevailing, but there are also radiating ribs. In the inner shell-layers little more than longitudinal striation is seen: the innermost are perforated by small punctiform pits. The inner layers are polished and glossy, the outermost seems to be opaque.'

Except that the Shropshire specimens do not reveal the punctiform pits on the innermost layer and that the radiating ribs are not seen, the above description exactly applies to the two Comley shells, both of which were found associated with *Billingsella lindstrœmi* and *Acrothele coriacea*; Linnarsson's specimens were obtained from 'loose masses' of bituminous limestone belonging to the strata with *Paradoxides forchammeri*, and associated with the same two species and also '*Orthis exporrecta*.' For some reason that is not explained, Dr. Walcott [1] refers these blocks to the *Paradoxides-œlandicus* Zone.

Neither of the two Comley specimens exhibits the interior surface, and only a very small portion of the exterior is seen in one of them (see fig. 23 *a*). This is near the umbo, and shows concentric striations, but no trace of radiating ribs. In both specimens the shell is thick, and consists of several layers. In one of them are two raised bands (see fig. 23 *b*) on one of the inner layers diverging at an acute angle from the apex, recalling the 'flanges' noted by Dr. Matley [2] in a fragmentary specimen that he referred with some hesitation to *Lingulella*. A minute shell (fig. 25) possibly represents a young form of the species.

Locality and horizon.—Comley, Middle Cambrian; from the *Billingsella* Beds, horizon Bc.

OBOLUS (?) GIBBOSUS, sp. nov. (Pl. XXII, figs. 20 & 21.)

Type-specimen [2119].

Diagnosis.—Ventral valve: outline a wide oval, from which the apex extends well back beyond the posterior margin, so that the shell is somewhat pear-shaped; convexity very strong and fairly even in curvature, apex curved down to a height above the marginal plane of the valve that is less than half the maximum height of the valve; area more or less concave, inclined at an angle of about 45°; shell thick, marked by a few raised radiating lines, crossed by concentric bands of varying depths of colour, and also by the ragged edges of successive layers of shell-material.

Interior without marks, so far as known from internal casts.

Dorsal valve: outline oval, narrowing slightly posteriorly, strongly convex, curvature flattening a little anteriorly; surface marked by several ragged edges of shell-material; interior with a slight oval prominence under the umbo, on either side of which lie two ill-defined concavities; otherwise devoid of vascular marks.

[1] 1912, p. 424.
[2] 1911, p. 301 & pl. xxvi, fig. 7.

Dimensions in millimetres.

Ventral valves	[2119]...	Length=3·5.	Width=3·0.	Height=1·1.
	[677]...	Length=2·5.	Width=2·0.	Height= ?
Dorsal valves	[2120]...	Length=2·8.	Width=2·6.	Height=0·66.
	[676]...	Length=2·5.	Width=2·25.	Height= ?

Locality and horizon.—Comley, Middle Cambrian; from the *Billingsella* Beds, horizon Bc.

OBOLUS (?) cf. SCHMALENSEEI Walcott. (Pl. XXII, figs. 22 *a* & 22 *b*.)

Obolus schmalenseei Walcott, 1912, U.S. Geol. Surv. Monogr. vol. li, p. 412 & pl. xxx, figs. 19, 19 *a*–19 *e*.

Lingulella (?) spp. *pars*, Matley, 1911, Q. J. G. S. vol. lxvii, p. 301 & pl. xxvi, figs. 8 *a* & 8 *b*.

Additional specimens possessing the sub-pentagonal form described by Dr. Matley have come to light since he wrote his notes on the brachiopoda from the *Paradoxides* Beds of Comley.

In size and general form they are very like *O. schmalenseei*, but they lack the fairly strong internal marks shown for that species in Walcott's figures. In the dorsal valve there is a central prominence and also two ill-defined concavities under the umbo as in *O. gibbosus*.

The specimen figured with Dr. Matley's notes is there called the interior of a brachial valve. From the lateral view there figured it seems more like a ventral.

The dorsal valve now figured [689] has the length and width equal, the convexity is strong, the test consists of several layers, the exterior is marked by the concentric edges of laminæ, and the interior by an ill-defined central ridge extending to a quarter or a third of the length of the shell, with ill-defined hollows on each side under the umbo.

Length = 3 mm.

Locality and horizon.—Comley, Middle Cambrian; from the *Billingsella* Beds, horizon Bc.

OBOLUS (?) sp. indet. *a*. (Pl. XXIII, fig. 29.)

A single valve [1604], that is referred to this genus on account of its shape, was found with crushed specimens of *Acrotreta* and fragments of *Hyolithellus micans* in fine blue shale, which is mapped as belonging to Horizon Ba_2.

Dimensions.—Length = 2·2 mm.; width = 2 mm.

OBOLUS (?) sp. indet. *b*. (Pl. XXIII, fig. 28.)

A rather large single valve [162 *b*], also referred to the genus, was found associated with *Acrotreta* in sandy shale mapped as belonging to Horizon Bb_2.

The specimen is remarkable for its strong convexity and the wide flattened margin of the cast, indicating a thick shell.

Dimensions.—Length = 3·2 mm.; width = 2·7 mm.

Lingulella Salter.

Lingulella viridis, sp. nov. (Pl. XXII, figs. 10–12.)

Type-specimen, a dorsal valve [97].

Diagnosis.—General form ovate, a little acuminate posteriorly; apical angle in the dorsal valve about 60°, in the ventral slightly less; the two valves are about equally convex; area, in the dorsal valve, apparently in the same plane as the margin of the valve, in the ventral rising at a gentle angle.

Exterior of both valves marked with from three to six principal lines of growth, showing numerous, very fine, concentric striæ between them, also many radiating striæ only visible under a strong magnifier.

Interior of dorsal valve (only known from casts) with two gently convex, curved ridges, extending over the middle third of the length of the valve, convex towards the centre-line and tapering to points anteriorly; within these ridges and back towards the apex the surface is roughened by minute projections, outside them it is smooth and polished; faint indications of linear marks are sometimes visible in the roughened area, but no muscle-scars have been detected.

Area gently convex and, in the dorsal valve, separated by a very narrow space from the umbonal portion of the shell; marked by three to six sinuous ridges that are strong as compared with the concentric striæ on the body of the shell.

Dimensions.—The type-specimen has a length of 5 mm.; more usually the shells are from 2 to 3 mm. in length. The convexity is about ·2 of the length, and the width ·8 in dorsal valves and ·7 in ventral valves.

Observations.—There is no good interior of the ventral valve. Fig. 10 shows an internal cast from which the shell-substance has been in part cleared away.

In form and external characters the species seems near to *L. nathorsti* Linnarsson; but the internal marks of that species, so far as known, and the details of the area of the dorsal valve are very different.

Locality and horizon.—Comley, Lower Cambrian; from the *Strenuella* Limestone, horizon Ac_4, and sparingly from the *Protolenus* Limestone, horizon Ac_5.

Lingulella nicholsoni Callaway.

Lingulella nicholsoni Callaway, 1874, Q. J. G. S. vol. xxx, p. 196.
Lingulella nicholsoni Callaway, 1877, Q. J. G. S. vol. xxxiii, p. 668 & pl. xxiv, figs. 11, 11 *a*–11 *b*.
Lingulella nicholsoni (Callaway), Walcott, 1912, U.S. Geol. Surv. Monogr. vol. li, p. 522 & pl. xxx, figs 3, 3 *a*–3 *f*.

Dr. Callaway records[1] the discovery of this species, together with 'the Shineton graptolites,' in shales east of Lawley Hill.

[1] 1879, p. 759.

The area 'east of Lawley Hill' is a continuation of the Comley Cambrian area—the stratigraphical relations to the beds which I have studied are unknown. The horizon is, therefore, lettered Cx.

LINGULELLA cf. FERRUGINEA Salter.

Cf. *Lingulella ferruginea* Salter, 1867, Q. J. G. S. vol. xxiii, p. 340, fig. 1.
Cf. *Lingulella ferruginea* Salter, Walcott, 1912, U.S. Geol. Surv. Monogr. vol. li, p. 496; pl. xxix, figs. 1, 1 *a*–1 *w*, 2, 2 *a*–2 *f*; pl. xxx, fig. 1; pl. xxxi, figs. 3, 3 *a*–3 *c*; and pl. xxxv, figs. 4, 4 *a*–4 *b*.
Lingulella cf. *ferruginea* Salter, Matley, 1911, Q. J. G. S. vol. lxvii, p. 300 & pl. xxvi, figs. 5–6 *b*.

No further evidence as to this form has come to light since Dr. Matley's notes were written.

Locality and horizon.—Comley, Middle Cambrian; from the *Paradoxides-rugulosus* Sandstone and from the *P.-davidis* Flags, horizons Bb_4 & Bb_5.

LINGULELLA sp. indet.

Lingulella spp. indet., Matley, 1911, Q. J. G. S. vol. lxvii, p. 301, *pars*.

Dr. Matley calls attention to another 'small oval form' found in the *Paradoxides-rugulosus* Sandstone, horizon Bb_4.

OBOLELLIDÆ Walcott & Schuchert.

OBOLELLA Billings.

OBOLELLA ATLANTICA Walcott.

Obolella atlantica Walcott, 1890, Proc. U.S. Nat. Mus. for 1889, vol. xii, p. 36.
Obolella atlantica Walcott, 1912, U.S. Geol. Surv. Monogr. vol. li, p. 589, text-fig. 51 & pl. lv, figs. 1, 1 *a*–1 *i*.

Obolella atlantica is represented at Comley by two forms, which are readily distinguished one from the other, but are so closely allied to Walcott's species that they are described here as varieties.

OBOLELLA ATLANTICA, var. COMLEYENSIS nov. (Pl. XXII, figs. 6–9; text-fig. 1.)

This is the small, round, whitish brachiopod so frequently met with in the *Olenellus* Limestone of the Comley Quarry. Usually the specimens are very poorly preserved, but occasionally good internal casts and exteriors are to be found.

The two valves are nearly circular, and have the same degree of convexity. The exterior answers closely to the description and figures given by Walcott. The interior differs a little from them in the development of the vascular marks; the size is uniformly smaller; and the transverse diameter is always a little greater than the length.

Dimensions.—Length = 3·5 to 3·8 mm.; width = 3·7 to 4·0 mm.; height = ·7 to ·9 mm.

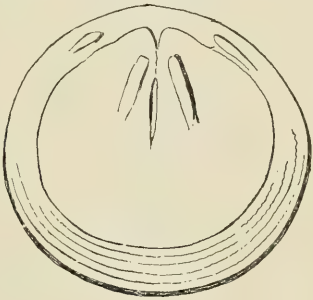
Observations.—In well-preserved casts of the ventral valve (figs. 6 & 9 & text-fig. 1), the cast of the pedicle-tube is usually

visible, and points upwards and backwards at an angle with the plane of the valve-margin ; on each side of it obtuse prominences project horizontally backwards from the convex body of the cast; at about a third of the length of the valve from the apex two comma-shaped prominences are situated, having their points directed forwards and nearly meeting at the centre-line ; beyond the swollen ends of the commas, ridges extend forwards and outwards, and between them and the centre-line, other ridges, one on each side, may sometimes be detected running in parallel directions ; traces of a backward prolongation of the outermost pair of ridges are occasionally observed (see Pl. XXII, fig. 9).

In the cast of the dorsal valve (Pl. XXII, fig. 7 & text-fig. 1) a central depression usually extends from the posterior border to about

Fig. 1.—Obolella atlantica, *var.* comleyensis *nov.* × 10. *Diagrams of internal casts of the ventral and dorsal valves, showing all marks observed in the several specimens.*

Ventral



Dorsal

half the length of the valve ; on each side raised lines diverge forwards, and are traceable for about the same distance ; from the back of the convex body of the cast obtuse prominences project horizontally backwards, similar to those of the ventral valve but nearer to the centre-line ; beyond these the body of the cast is hollowed out, the hollows being terminated laterally by projecting elongated bosses, more or less parallel to the margin of the valve.

In both valves a wide flattened or even recurved space extends all round the convex body of the cast.

All the internal marks that have been observed in various specimens have been combined in the outline restoration (fig. 1, above).

The shell-substance is calcareous.

Dr. J. Kiær, in his work on the *Holmia* fauna of Tömten, describes and figures a species, *O. rotundata*, that is, at first sight, very like the variety *comleyensis*. The general form is almost exactly the same, and the resemblance between the dorsal valves is particularly striking.

The Tömten shell is rather more pointed posteriorly than the Comley form ; it is about 25 per cent. larger in linear dimensions ;

the vascular sinuses of the ventral valve are usually, but not invariably, bent out widely so as to follow a curve that is subparallel to the margin, instead of being straight; the pedicle-tube appears to be stouter and more triangular.

From Dr. Kiær's figures the shell appears to have been thick, and to have the retroussé margin that is so characteristic of the Comley shells, but possibly this similarity may be due to its preservation in shale.

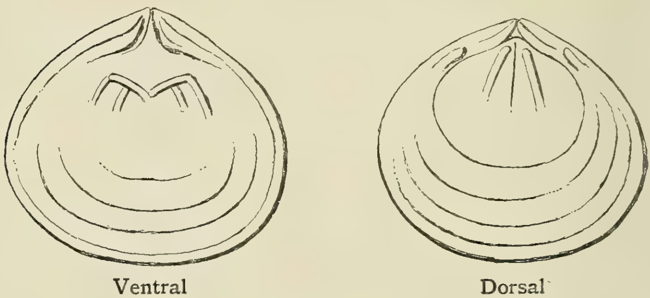
The variety *comleyensis* is nearer to the American form of *O. atlantica* (that is, *O. rotundata*), but not so near as the variety *transversa*.

Locality and horizon.—Comley, Lower Cambrian; from the *Olenellus* Limestone, horizon Ac_2, and from the *Microdiscus-bellimarginatus* Limestone, horizon Ac_3.

OBOLELLA ATLANTICA, var. TRANSVERSA nov. (Pl. XXII, figs. 1–5; text-fig. 2.)

This variety occurs at a higher horizon than *comleyensis*, and always in association with a different group of trilobites. In

Fig. 2.—Obolella atlantica, *var.* transversa *nov.* × 5. *Diagrams of internal casts of the ventral and dorsal valves, showing all marks observed in the several specimens.*



point of size it is nearer to the American form, but differs in having both valves more transverse and also in the details of the internal marks. From the variety *comleyensis* it differs in general shape and size; in having a relatively thinner shell; in the external surface, which is more in accord with Walcott's description; and in the internal features, which are proportionately smaller. Though a larger shell, it appears to be built on more delicate lines.

Dimensions.—The lengths observed vary from 5·3 to 6·5 millimetres, the widths are from an eighth to a tenth greater, the convexity averages about a fifth of the length.

All the internal marks shown on several casts have been combined in text-fig. 2. In order that the internal characters of the

two varieties may be readily compared, the scale of enlargement used in fig. 2 is half of that used in fig. 1 (p. 343).

The exterior is often beautifully preserved, 'the fine radiating striæ that are sometimes raised lines'[1] are particularly well marked (Pl. XXII, fig. 5).

Locality and horizon.—Comley, Lower Cambrian, from the *Strenuella* Limestone, horizon Ac_4.

OBOLELLA (?) GROOMII Matley. (Pl. XXI, fig. 27.)

Obolella (?) groomii Matley, 1902, Q.J.G.S. vol. lviii, p. 137 & text-figs. 1–2.
Obolella groomii Matley, Walcott, 1912, U.S. Geol. Surv. Monogr. vol. li, p. 595 & text-figs. 52 A–52 B.

Several examples of this species have been found in the mottled and greenish-grey beds at the base of the Lower Comley Sandstone, at the Road Quarry in the Cwms. Fragments are readily identified by the external characters, the edges of successive lines of growth being very sharp, and almost 'undercut' in their sculpture. The shell-substance is well preserved in the sandstone, and appears to be corneous. It is doubtful whether it was ever to any considerable extent composed of carbonate of lime, for the shells are not preserved as empty casts notwithstanding the open, sandy nature of the rock.

As with the Malvern specimens, dorsal and ventral valves cannot be distinguished with any certainty, and no interiors have been met with. In view of these facts the generic reference must remain doubtful.

Locality and horizon.—Comley, the Cwms sub-area; Lower Cambrian, horizon Ab_1.

ACROTRETIDÆ Schuchert.

ACROTHELE Linnarsson.

ACROTHELE CORIACEA Linnarsson. (Pl. XXIII, figs. 19 *a*–22 *b*.)

Acrothele coriacea Linnarsson, 1876, Bihang K. Svenska Vetensk.-Akad. Handl. vol. iii, No. 12, p. 21 & pl. iv, figs. 44–48.
Acrothele cf. *granulata* Linnarsson, Matley, 1911, Q. J. G. S. vol. lxvii, p. 302 & pl. xxvi, figs. 9 *a*–9 *b*.
Acrothele coriacea Linnarsson, Walcott, 1912, U.S. Geol. Surv. Monogr. vol. li, p. 642 & pl. lvi, figs. 1, 1 *a*–1 *i*.

The specimens submitted to Dr. C. A. Matley were not wholly satisfactory; he noticed, however, that the position of the apex of the ventral valve was more in accord with that of *A. coriacea* than with that of *A.* (*Redlichella*) *granulata*. Since his notes were written, Dr. C. D. Walcott's work has appeared, with details as to the aspect of the granulations of both species.

A number of additional specimens have now come to light from the *Billingsella* Bed of Caradoc Dingle, and these agree in all respects with the published descriptions of *A. coriacea*. The shells usually split along one of the inner layers, which are bright and glistening. The exterior surface of the ventral valve near the

[1] C. D. Walcott, 1912, p. 589.

margins, and on the greater part of the false area, is covered with rugose concentric ridges, which give place to granulations on the central parts of the shell.

Of the dorsal valve Dr. Walcott (*op. cit.* p. 642) says:—

'On some shells a slight depression or flattening extends (from the apex) to about the middle of the valve.'

In the Comley specimens this feature is seen in exfoliated dorsal shells (fig. 22 *a*). If, however, the successive laminæ are removed, the depression becomes increasingly distinct, and, when the surface of the internal cast is reached, there is a distinct central hollow indicating a well-developed ridge or septum on the interior of the shell reaching nearly as far as the anterior border (fig. 22 *b*).

The characters of the exterior of the two valves are somewhat dissimilar. The dorsal valve seems to be covered with rugose concentric ridges, like those on the margins and false area of the ventral.

Dimensions.—Greatest length observed = 9 mm.; the usual length = 5 to 6 mm.

Locality and horizon.—Comley, Middle Cambrian; from the *Billingsella* Beds, horizon Bc; from the *Paradoxides-davidis* Flags, horizon Bb_5; and from the *Orusia* Shales, horizon Ca.

Acrotreta Kutorga.

Acrotreta sagittalis Salter.

Obolella sagittalis Salter, 1866, Rep. Brit. Assoc. (1865) p. 285.
Acrotreta (*Linnarssonia*) *sagittalis* Salter, Matley, 1911, Q. J. G. S., vol. lxvii, p. 302 & pl. xxvi, figs. 10 *a*–10 *b*.
Acrotreta sagittalis Salter, Walcott, 1912, U.S. Geol. Surv. Monogr. vol. li, p. 704 & pl. lxxi, figs. 2, 2 *a*–2 *h*, 3, 3 *a*–3 *j*.

A few valves that are referred to this species occur in association with *A. schmalenseei* var. at the two sections on the Shoot-Rough Road, and in the *Billingsella* Bed of Caradoc Dingle, horizon Bc.

Acrotreta schmalenseei Walcott, var. matleyi nov. (Pl. XXII, figs. 26–30, 32, & (?) 31.)

Acrotreta aff. *socialis* Seebach, Matley, 1911, Q. J. G. S. vol. lxvii, p. 303 & pl. xxvi, figs. 11 *a*–13 *b*.
Acrotreta schmalenseei Walcott, 1912, U.S. Geol. Surv. Monogr. vol. li, p. 709 & pl. lxx, figs. 1, 1 *a*–1 *s*.

The study of about a hundred additional examples of the Comley form of this species, which have been obtained from the original rock-bed since Dr. Matley wrote his notes, shows that the ventral valve is persistently different in form from that depicted in Dr. Walcott's figures; in the absence of direct comparison with Scandinavian specimens, it seems therefore advisable to refer to them under a varietal name.

In the specimens examined by Matley, the anterior margins of the ventral valves were never satisfactorily cleared of matrix; with the new material available it has been possible to do this in many instances, and to establish the fact that the apices are always

situated over or behind the posterior margin of the opening of the valves, never in front of it, and that the anterior slope is distinctly convex. In all other respects the shells accord with Walcott's figures and description.

Dimensions.—The lengths observed for ventral valves vary from 1 to 3 mm.; the width is 1·25 of the length, and the height is about ·5 of the length.

Locality and horizon.—Comley, Middle Cambrian; from the *Billingsella* Beds, horizon Bc, also doubtfully from the *Paradoxides-davidis* Flags, horizon Bb_5.

ACROTRETA SOCIALIS Seebach (?). (Pl. XXII, fig. 35.)

Acrotreta socialis Seebach, 1865, Zeitschr. Deutsch. Geol. Gesellsch. vol. xvii, p. 341 & pl. viii *a*, figs. 1–4.
Acrotreta socialis Seebach, Walcott, 1912, U.S. Geol. Surv. Monogr. vol. li, p. 711 & pl. lxxii, figs. 3, 3 *a*–3 *c*, 4, 4 *a*–4 *c*.

Some small ventral valves, found associated with *Acrothyra comleyensis* and *Dorypyge lakei*, agree with some of the figures of this species given by Dr. Walcott.[1] The anterior and posterior slopes are nearly straight, the apex is well forward from the posterior margin, the foramen is distinctly visible behind it, the height is about a half of the length, the surface is striated with fine concentric lines, the false area is moderately well-defined, and the vertical groove is narrow.

Dimensions.—Length=2 mm., width=2 mm., height=·8 mm.

These shells differ from Walcott's description of Seebach's species in being rather smaller, in having finer concentric striæ, and in the narrower vertical groove.

From *A. schmalenseei* they differ very decidedly in the position of the apex and in the anterior slope being almost straight, instead of curved.

Locality and horizon.—Comley, Middle Cambrian; from the *Dorypyge-lakei* Flags, Ba_5.

ACROTRETA sp. indet. *a*. (Pl. XXII, fig. 33.)

A few valves have been found in association with *A. schmalenseei* var. *matleyi*, which appear to be distinct from any described species, but are too scarce or indifferently preserved to be definitely named.

They are distinguished by (1) the ventral valve being very elevated (it is almost as high as it is long); (2) the straight anterior slopes; (3) the false area being inclined backwards; (4) the absence of the vertical groove on the false area in the only exterior known.

The exterior is marked by fine concentric lines, set more widely apart than in *Acrotreta schmalenseei*.

Dimensions.—Length = 1·5 mm.; width = 1·5 mm.; height = 1·25 mm.

[1] 1912, pl. lxxiii, figs. 4, 4′, 4″, 4 *a*, 4 *a*′, 4 *a*″.

Locality and horizon.—Comley, Middle Cambrian; from the *Billingsella* Beds, horizon Bc.

ACROTRETA sp. indet. *b*. (Pl. XXIII, fig. 30.)

A few valves were found in fine blue shale in the bed of Comley Brook; all are much crushed. Fig. 30 [1606] represents one of the best-preserved ventral valves.

Dimensions.—Length=1·2 mm.; width=1·4 mm.; height, greater than ·4 mm.

Locality and horizon.—Comley, Middle Cambrian; horizon Ba_2.

ACROTRETA sp. indet. *c*. (Pl. XXII, fig. 34.)

Two dorsal valves [1621 *a*, 1622] that appear to belong to the genus were found in sandy shale east of Hill-House Ridge.

The internal characters are well marked, but there is not sufficient material for specific determination.

Dimensions in millimetres.

1621 *a*. Length=2·4, width=2·5.
1622. Length=1·5, width=1·7.

Locality and horizon.—Comley, Middle Cambrian; horizon Bb_2.

ACROTHYRA Matthew.

Dr. G. F. Matthew [1] proposed the generic name *Acrothyra* for certain *Acrotreta*-like forms having

'the ventral valve elongate-conical, with the apex either overhanging the cardinal line, or but little in front of it; [and the interior] with a long, narrow, or a quadrate visceral callus, extending forward from the foramen about a third of the length of the valve and widening as it goes.'

Dr. C. D. Walcott,[2] in his monograph, adopts the separate generic term; but he observes that

'this genus is intimately related to *Acrotreta*, and, except for the presence in some species of a well-marked visceral area of a type not known in *Acrotreta*, there would be difficulty in assigning more than subgeneric value to it.'

The Comley specimens that are here assigned to Matthew's genus are very like *Acrotreta*; but they have a strongly-marked visceral area in the ventral valve, and in the dorsal valves the main vascular sinuses are well developed.

ACROTHYRA COMLEYENSIS, sp. nov. (Pl. XXIII, figs. 1 *a*–8; text-fig. 3, p. 349.)

Acrothyra sp., Cobbold, 1916, Rep. Brit. Assoc. (Manchester, 1915) p. 119.

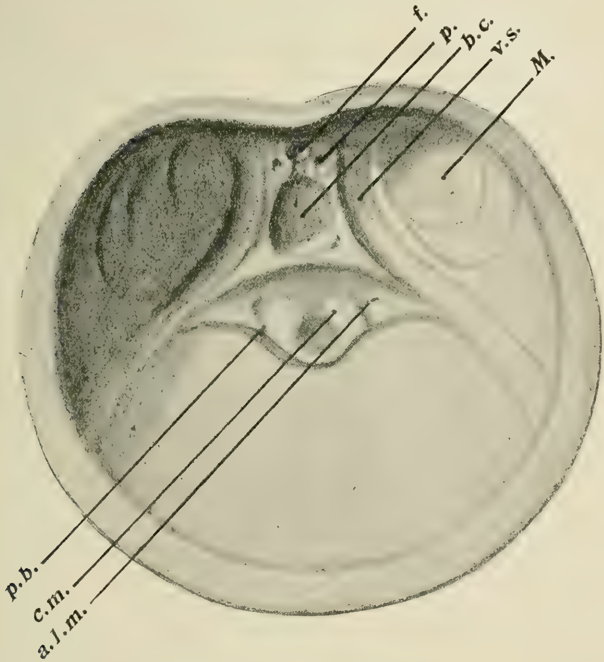
Type-specimen [1710].

Diagnosis.—Ventral valve subcircular, conical; apex pointed, and somewhat in advance of the posterior margin; false area ill-defined, traversed by a broad vertical channel and inclined forwards

[1] Bull. Nat. Hist. New Brunswick, vol. iv (1901) pt. 4, No. 19, p. 303.
[2] 1912, U.S. Geol. Surv. Monogr. vol. li, p. 716.

at an angle of 70° to 80°; interior showing a bell-shaped cavity connected posteriorly with the foramen by a short groove in the wall of the cavity; main vascular sinuses deep on each side of the cavity, then disappearing, except in a few instances when they are traceable a long way towards the anterior margin; cardinal scars large; parietal band sinuous, connecting the forward ends of the

Fig. 3.—Acrothyra comleyensis, *sp. nov.* × *about 24. Restoration of the interior of the ventral valve.*



[*f* = Foramen; *p* = Minute pit; *b.c.* = Bell-shaped cavity; *v.s.* = Vascular sinus; *M.* = Cardinal muscle-scar; *p.b.* = Parietal band; *c.m.* = Central muscle-scar (?); *a.l.m.* = Anterior lateral muscle-scar (?).]

deeper parts of the vascular sinuses and passing the centre-line at about the half-length; muscle-scars (?) represented by four slightly-raised prominences almost touching the parietal band; two little pits occur in the wall of the bell-shaped cavity on each side of the foramen and a little in advance of it. Associated dorsal valves subcircular, convex, with apex depressed and marginal; interior with a median ridge extending about two-thirds the length of the valve, sometimes interrupted, sometimes only weaker at the middle of its course, from which point two branches diverge slightly and then pass forwards parallel to the median ridge; main vascular sinuses well developed posteriorly; cardinal muscle-scars large.

Shell-substance in both valves corneous, thick, and formed of many laminæ; exterior marked by very closely-set concentric striæ; inner layers occasionally showing faint traces of radiating striæ.

Dimensions.—Lengths=from 1·9 to 3·25 mm.; proportion of length to width=about 1 to 1·1; of length to height, in ventral valves=about 1 to ·33, in dorsal valves=1 to ·2.

Observations.—The internal characters seen in the casts vary so much in size, in proportion to the diameters, as to suggest that more than one species may be present. These divergences are, however, due to the amount of shell remaining on the cast, and disappear on its removal.

In fig. 2, Pl. XXIII, representing an internal cast of the ventral valve from which all the shell-substance has come away, the bell-shaped cavity extends to about a third of the length of the shell; fig. 3 represents a cast with some of the shell left on it, and here the cavity extends to about a fifth of the shell-length; in fig. 4, from a cast to which much shell adheres, the extension is but to a twelfth, and in this case the visceral cavity has the circular form seen in the young shell. Figs. 1 *a* to 1 *e* are five views of the apex of one ventral valve, from which four successive layers of shell were removed. In fig. 1 *a* the exterior of the shell is seen; in 1 *b*, after the first exfoliation, the visceral cavity is represented by the circular prominence, while in the succeeding figures the cavity assumes its more normal shape. The various forms are evidently the internal casts at successive stages of growth.

Variation.—Occasionally a full-sized shell is found, in which the cavity retains somewhat of the circular shape seen in the young shell (fig. 7, Pl. XXIII).

The relations of *Acrothyra comleyensis* to other species are discussed with those of *A.* cf. *sera* (below). It may, however, be remarked here that indications of the two little pits near the foramen may be seen in the figures of the following species in Dr. C. D. Walcott's monograph:—

Acrotreta definita Walcott, pl. lxiv, figs. 2 *c*, 2 *c′*.
Acrotreta kutorgai Walcott, pl. lxv, figs. 36, 36′, 3 *c*, 3 *c′*.
Acrotreta argenta Walcott, pl. lxvii, figs. 5 *a*, 5 *b*, 5 *b′*.

They are also seen in *A.* cf. *sera*; see Pl. XXIII, fig. 10, of this paper.

Locality and horizon.—Comley, Middle Cambrian. *A. comleyensis* is found associated with *Dorypyge lakei* Cobbold, at two local horizons, Ba_1 and Ba_3; in the former, fragments of *Paradoxides* have also been found.

ACROTHYRA cf. SERA Matthew. (Pl. XXIII, figs. 9 *a*–18.)

Acrothyra signata sera Matthew, 1902, Bull. Nat. Hist. Soc. New Brunswick, vol. iv, pt. 5, No. 20, pp. 383, 384 & pl. xiii, figs. 3 *a*–3 *e*.
Acrothyra sera Matthew, Walcott, 1912, U.S. Geol. Surv. Monogr. vol. li, p. 718 & pl. lxxx, figs. 4, 4 *a*–4 *c*, 5, 5*a*–5 *d*, 6, 6*a*–6 *i*, 7, 7 *a*–7 *b*, 8 (?). Reasons are given for grouping several of Dr. Matthew's species or varieties under one specific name.

A form which is very close to, if not identical with, the Cape Breton species, occurs in considerable quantity in the granular

portion of the Black Limestone of Comley, now called the *Lapworthella* Limestone.

The ventral valve is conical and nearly circular in outline, somewhat flattened posteriorly, and has a very slight indentation at the middle line; the posterior slope may be vertical (fig. 12), or inclined backwards (fig. 11), or a little forwards (fig. 9 *a*); the anterior and lateral slopes are nearly straight; the false area is ill-defined and traversed by a vertical furrow, indistinct towards the margin. The internal marks vary with the amount of exfoliation. Fig. 9 *a* shows the cast of an interior where slight exfoliation has occurred; fig. 9 *b* represents the same specimen after the material of the apical callosity had been removed. It discloses the cast of the elongated visceral cavity and those of the vascular sinuses and cardinal muscle-scars. Fig. 10 shows an interior in which the visceral cavity and the two little pits are well seen. The foramen itself is lost in the broken posterior margin, but the narrowing of the visceral cavity to the notch or groove connecting it with the foramen is quite obvious. The casts of the little pits are rarely or never seen; they are not obvious, as in *A. comleyensis*.

Occasionally the casts of the vascular sinuses are proportionally wider apart than they are in the more typical form represented in fig. 9 *b*.

The dorsal valve is very little wider than long, rather strongly convex, and has the apex bent down almost to the margin. In the interior (figs. 15 & 17) there is a septal ridge which widens at its termination; the vascular sinuses are well developed posteriorly; between them and the septal ridge are two elongated prominences; the cardinal muscle-scars are large.

The shell-substance is corneous and very thick, both in the dorsal valve (see fig. 14 *b*) and in the apical callosity of the ventral. The exterior is marked by concentric striæ, fairly closely set and apparently strongest on the dorsal valves; where exfoliation has occurred, radiating striæ are clearly seen.

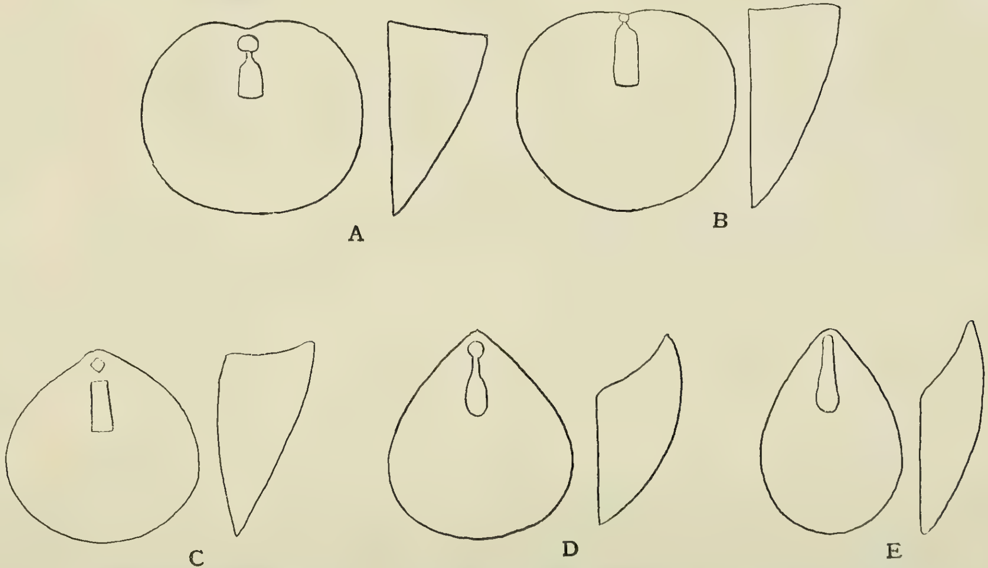
Dimensions.—The lengths vary from 1·5 to 3 mm.; the proportion of length to width is about 1 to 1·1; and that of length to height is 1 to ·4 in ventral, and 1 to ·25 or ·3 in dorsal valves.

Localities and horizon.—Comley, Lower Cambrian, from the *Lapworthella* Limestone of Comley Quarry, horizon Ad; also near Neves' Castle, in the Wrekin district.

COMPARISON BETWEEN *ACROTHYRA COMLEYENSIS* AND *A.* cf. *SERA*.

	A. comleyensis.	*A.* cf. *sera.*
(1) Posterior margin ...	decidedly notched.	almost straight.
(2) Inclination of posterior slope	forwards.	forwards, vertical or backwards.
(3) Concentric striæ ...	weak and very close-set.	comparatively strong.
(4) Radiating striæ ...	barely visible.	moderately strong.
(5) Visceral cavity ...	widely bell-shaped.	elongate.
(6) Casts of little pits	very obvious.	not obvious.
(7) Septal ridge of dorsal valve	strong posteriorly, weak centrally, reaching far forwards.	weak posteriorly, widening centrally.

Fig. 4.—*Outline-sketches of the interiors and lateral aspects of five forms of ventral valves of the genus* Acrothyra, *omitting the muscle-scars and vascular sinuses.*



A. *A. comleyensis* Cobbold.
B. *A.* cf. *sera* Matthew, Cobbold.
C. *A. signata sera* Matthew.
D. *A. signata* Matthew.
E. *A. proavia* Matthew.

[Figs. C, D, & E are copied from Matthew.]

Many of Dr. Walcott's figures of *Acrothyra sera* (*op. cit.* pl. lxxx) may be matched from the Comley specimens; but the vertical groove on the false area in his figures 4 a'' & $5''$ is much stronger than any noted from Comley.

The description given by Dr. Matthew under *A. signata sera* (*op. cit.* p. 383) applies fairly accurately to the Comley shells. Of the interior he says that it has

'Near the hinge a thick rectangular callus hollowed at the middle, with a depression that deepens towards the hinge; from this it is divided by a low transverse ridge, behind which is a pit leading to the foramen.'

He makes no mention of the connexion between the depression and the foraminal pit, such as is seen in *A. comleyensis* and in *A.* cf. *sera*. In his description of *A. signata* (*op. cit.* p. 381), however, he says:—

'There is a strong narrow callus, one-third the length of the valve, bounded by a raised ridge at the sides and in front; at the front of this callus is an oval pit from which a groove runs backward nearly to the apex of the shell, where it is supposed to connect with the foramen.'

In *A. proavia*, the type of the genus, no mention is made of a connecting groove; but the hollow is represented in Matthew's figures (*op. cit.* text-fig. 2, p. 386, & pl. ii, figs. 4 *b*–5 *b*) as continuous nearly as far as the apex. Apparently in this species the hollow, the groove, and the foraminal pit are merged into one.

These differences appear to be connected with the elongation of the valve backwards, though which form is the more primitive cannot be determined upon the present evidence.

Text-fig. 4 (p. 352) is introduced so as to show graphically the modifications here mentioned.

BILLINGSELLIDÆ Schuchert

Billingsella Hall & Clarke.

Billingsella cobboldi Matley.

Billingsella cobboldi Matley, 1911, Q. J. G. S. vol. lxvii, p. 305 & pl. xxvi, figs. 20–23.

Locality and horizon.—Comley, Middle Cambrian; from the *Paradoxides-davidis* Flags, horizon Bb_5.

Billingsella lindstrœmi, var. salopiensis Matley. (Pl. XXIII, figs. 24 *a*–24 *c*.)

Billingsella lindstrœmi Linnarsson, var. *salopiensis* Matley, 1911, Q. J. G. S. vol. lxvii, p. 303 & pl. xxvi, figs. 14 *a*–17 *c*.

Since this form was described by Dr. Matley, a large number of additional specimens have been obtained from the *Billingsella* Bed of Caradoc Dingle, many being more complete than those figured with his notes. From these it appears that the apex of the ventral valve is recurved over the posterior border to a greater extent than is shown in his figure, hiding the convex deltidium, which has not been observed.

An extreme case, probably an old individual, is now figured.

Locality and horizon.—Comley, Middle Cambrian; from the *Billingsella* Beds, horizon Bc; also, sparingly, from horizon Bb_2.

Billingsella sp. indet. (Pl. XXIII, figs. 23 *a*–23 *c*.)

A single ventral valve, represented by the external and internal casts [1879, 1880], was found in the matrix of the Comley Breccia-Bed. The specimens do not preserve any of the finer internal markings, and the external characters are but poorly indicated. These consist of some twenty-five angular (?) radiating ribs, which increase at varying distances by interpolation, and are crossed by concentric lines of growth. The ribs are reproduced on the internal surface.

Dimensions.—Length = 8 mm.; width = 9·5 mm.; height = 1·6 mm.

Locality and horizon.—Comley, Middle Cambrian; from the Comley Breccia-Bed, *Paradoxides-intermedius* Grits, horizon Bb_1.

Orusia Walcott.

Orusia lenticularis Wahlenberg. (Pl. XXIII, figs. 25–27.)

Orthis (*Orusia*) cf. *lenticularis* Wahlenberg, Matley, 1911, Q. J. G. S. vol. lxvii, p. 306 & pl. xxvi. figs. 24–26.

Orusia lenticularis Wahlenberg, Walcott, 1912, U.S. Geol. Surv. Monogr. vol. li, p. 765 & pl. xcviii, figs. 1, 1 *a*–1 *p*, 2, 2 *a*–2 *k*, 3, 3 *a* & 3 *b*, 6, 6 *a*–6 *c*.

Since Dr. Matley wrote his notes additional specimens have been found at Comley, among which almost every variation figured by Dr. Walcott can be matched. There are also internal casts showing the fissures which represent the crural plates of the dorsal valve and the dental plates of the ventral mentioned,[1] but not figured, by Dr. Walcott; the former are comparatively near together and sometimes converge, the latter are wide apart and divergent.

Locality and horizon.—Comley, Upper Cambrian; from the *Orusia* Shales, horizon Ca.

VI. The Comley Pteropoda, etc.

Hyolithus Eichwald.

Hyolithus crassus, sp. nov. (Pl. XXIV, fig. 28.)

Type-specimen [2603].

Diagnosis.—Shell straight (so far as seen), apparently subquadrate in section, ratio of diameters about 1 to ·7, lateral angles well rounded, rate of taper uncertain; shell-substance of two layers—the inner thick, smooth, and calcareous, the outer thinner and marked with numerous, irregular, and very coarse wrinkles; aperture transverse on the ventral face, projecting forward on the dorsal, and sinuous at the sides.

Dimensions.—Apertural diameter, 5 or more millimetres. The length may have been from 40 to 50 mm.

[1] 1912, p. 767.

The wrinkles of the outer surface recall those of *H. corrugatus* Kiær[1]; they are, however, more irregular and less coarse than those shown in Dr. Kiær's figure. He regards his species as belonging to the sub-genus *Orthotheca*.

The resemblance in the shell-structure of this species to that of *H. sculptilis*, sp. nov. (p. 356) is very close, although the character of the sculpture differs radically.

Locality and horizon.—Comley, Lower Cambrian; from the *Protolenus* Limestone, Ac_5.

HYOLITHUS STRETTONENSIS, sp. nov. (Pl. XXIV, figs. 30 & 31.)

Hyolithus cf. *primævus* Groom, Cobbold, 1916, Rep. Brit. Assoc. (Manchester, 1915) p. 118.

Cf. *Hyolithus primævus* Groom, 1902, Q. J. G. S. vol. lviii, p. 116.

Type-specimen [1903].

Diagnosis.—Shell straight, tapering uniformly at rates which vary between 1 in 4·5 (apical angle 13°) and 1 in 7 (apical angle 8°); section a segment rather greater than a semicircle, ratio of diameters about 1 to ·66, dorsal side very slightly convex, ventral semicircular, lateral angles rounded; aperture in two planes, projection of dorsal lip about ·2 of the width; sculpture consisting of faint closely-set striæ of growth.

Dimensions.—Width of aperture = 6 to 7 mm.; total length = 30 to 40 mm.

HYOLITHUS STRETTONENSIS, var. BREVIS nov. (Pl. XXIV, fig. 32.)

From the same general horizon a variety, or allied species, is found, which has a rate of taper varying from 1 in 2·5 to 1 in 3·5 (apical angles 23° to 18°), and a rather smaller proportional projection of the dorsal lip.

Dimensions.—Width = about 5·5 mm.; length = 16 mm.

The variation in the apical angle is similar to that of *H. americanus* Billings,[2] which differs from *H. strettonensis* in having a greater proportional projection of the dorsal lip and a triangular section.

H. communis Billings[3] also has a greater projection of dorsal lip than *H. strettonensis*; it is more elongate, and its section is flattened both dorsally and ventrally.

A curious confusion appears to have crept in as to the subgeneric reference of *H. communis*. In the original description Billings distinctly refers to the projecting [dorsal] lip; he, however, describes an operculum under the same reference, which seems to belong to an *Orthotheca*. Walcott (1886, p. 136) adopts Billings's description, and then observes that Ford's species *H. emmonsi* seems to be a variety. From the original description (Ford, 1873, p. 214) this species is evidently an *Orthotheca*, and is recognized

[1] 1916, p. 25 & pl. iii, figs. 10 *a*–10 *b*.

[2] 1872, p. 215, text-figs. 2 *a* & 2 *b*

[3] 1872, p. 214.

as such by A. W. Grabau (1900, p. 655). G. Holm (1893, p. 30) places *Hyolithus communis* under *Orthotheca*, and other writers seem to have followed him.

H. strettonensis resembles *H. primævus* Groom [1] from Malvern, and may indeed be identical with it. Dr. T. T. Groom is, however, uncertain whether his species is an *Orthotheca* or a *Hyolithus* sensu stricto; and, until specimens elucidating this point are forthcoming, it seems advisable to describe the Comley form as a distinct species, lest a similar confusion to that mentioned above should arise.

Locality and horizon.—The Cwms, Church Stretton (a continuation of the Comley Cambrian in a south-westerly direction). Lower Cambrian. From the greenish-grey sandstone, horizon Ab_1 of the Road Quarry.

The variety *brevis* was found in beds of the same horizon at the north-eastern end of Caradoc Hill.

Hyolithus (?) sculptilis, sp. nov. (Pl. XXIV, figs. 25–27.)

Type-specimens [2583 & 2587].

Diagnosis.—Shell straight, or slightly tapering, sub-oval in section, with one side rather less convex than the other, ratio of diameters 1 to ·7; shell-substance of two layers—the inner calcareous, thick, and smooth internally, the outer thin and covered with short, parallel, transverse wrinkles arranged in longitudinal rows that are separated by lines of plain shell; occasionally two or more rows will coalesce, but as a rule they remain distinct. The wrinkles may be straight or crescentic, and sometimes those of one row are set at a sharp angle with those of the contiguous row. In one fragment, probably from the neighbourhood of the aperture, the rows are traversed and replaced by continuous ridges or lines of growth.

Estimated dimensions.—Length = 30–40 mm.; apertural diameter = about 4 mm.

Small fragments with the characteristic sculpture are plentiful in the *Protolenus* Limestone; in only one instance is the sectional form seen, and in no case is there anything like a complete shell; on this account the generic reference is given with reserve. At first sight the fragments suggest a reference to *Conularia*; there are, however, no re-entering suture-like lines such as are depicted in Tate's figures of his species *H conularoides*.[2]

Locality and horizon.—Comley, Lower Cambrian; from the *Protolenus* Limestone, Ac_5.

Hyolithus sp. indet. Operculum (Pl. XXIV, fig. 29).

An operculum, which cannot with certainty be referred to any accompanying shell occurs in considerable numbers in the *Protolenus* Limestone.

[1] 1902, p. 110 & text-figs. 17–24.
[2] 1891, p. 186 & pl. ii, figs. 1-1*a*.

It is somewhat elliptical in general outline: the conical dorsal portion has a slight elevation, is marked by numerous fairly-strong concentric and also radiating striæ; the ventral (upturned) portion is set nearly at right angles to the dorsal, and rises above the general plane of the plate to a height of about a third of the dorsi-ventral diameter. The angle at the apex of the conical portion is about 115°.

Dimensions.—Dorsi-ventral diameter = 7·5 mm.; transverse diameter = 9 mm.

Locality and horizon.—Comley, Lower Cambrian; from the *Protolenus* Limestone, horizon Ac_5.

Sub-genus **Orthotheca**.

HYOLITHUS (ORTHOTHECA) BAYONET Matthew. (Pl. XXIV, figs. 12–16.)

Orthotheca bayonet Matthew, 1899, Bull. Nat. Hist. Soc. New Brunswick, xviii, p. 193 & pl. iii, figs. 1 *a*–1 *e*.

Orthotheca bayonet Matthew, 1899, Trans. Roy. Soc. Canada, ser. 2, vol. v, sect. 4, p. 114 & pl. vii, figs. 1 *a*–1 *e*.

This species is of frequent occurrence at one horizon at Comley, and is represented a little lower in the series by a variety or mutation.

The more typical forms agree in all respects with the two descriptions given by Matthew, except that the rate of taper is about 1 in 6, and not 1 in 5 or 1 in 4 as given for the Newfoundland specimens, and that the ventral faces sometimes exhibit a few longitudinal striæ.

The declination of the orifice from the dorsal side to the ventral angle is well shown (fig. 15), as is also the concave outline of the dorsal lip (fig. 13).

Locality and horizon.—Comley, Lower Cambrian; from the *Protolenus* Limestone, Ac_5.

A variety which may be named STRIATUS (fig. 11) has more definite and regularly-arranged longitudinal striæ, and the growth-lines indicate that the declination of the aperture towards the ventral angle was slighter.

Locality and horizon.—Comley, Lower Cambrian; from the *Strenuella* Limestone, Ac_4.

HYOLITHUS (ORTHOTHECA) COMPRESSUS, sp. nov. (Pl. XXIV, figs. 17 *a* & 17 *b*.)

Type and only specimen [225, 226].

Diagnosis.—Shell, a curved elongated pyramid, rate of taper changing from 1 in 4 near the apex to 1 in 3 towards the aperture (equivalent angles 14° & 19°). Dorsal and ventral sides indistinguishable. Section, an elongated ellipse, ratio of axes 1 to ·33, lateral angles well rounded. Shell-substance thin, bluish grey, phosphatic (?). Surface: marked by transverse lines of growth,

spaced 4 to the millimetre. Aperture at right angles to the axis of the shell.

There appear to be no nearly-allied forms with which this species may be compared. The apical portion, if found detached, would be very similar to *Torelella.*

Locality and horizon.—Comley, Lower Cambrian; horizon Ac_2 (the *Olenellus* Limestone) of Comley Quarry.

HYOLITHUS (ORTHOTHECA) DE GEERI Holm (?).

Hyolithus (*Orthotheca*) *de geeri* Holm, 1893, Sver. Geol. Undersökn. ser. C, No. 112, p. 54 & pl. i, figs. 25–27.
Hyolithus Cobbold, 1912, Rep. Brit. Assoc. (Portsmouth, 1911) p. 114.
Hyolithus (*Orthotheca*) *de geeri* Holm, Cobbold, 1919, Geol. Mag. p. 150 & pl. iv, figs. 1–6.

Some of the casts mentioned in the British Association Report agree in cross-section and apical angle with Holm's species, but are not sufficiently well preserved for accurate determination. They are smaller than the type from Scandinavia.

Locality and horizon.—Comley, Lower Cambrian; from beds which are mapped as belonging to horizon Ab_2.

HYOLITHUS (ORTHOTHECA) sp. indet. *a*. (Pl. XXIV, fig. 34.)

An oval operculum, which appears to belong to the sub-genus *Orthotheca*, cannot be assigned to any associated shell. It is almost flat, the nucleus rising a very little above the plane of the margin; the exterior is marked by numerous concentric striæ and two lines on each side radiating from the nucleus (which is sub-central) towards the lateral much rounded angles.

Dimensions.—Dorsi-ventral diameter = about 3 mm.; transverse diameter = about 6 mm.

This operculum recalls that assigned by me with reserve to *H.* (*O.*) *de geeri* Holm, from the *Hyolithus* Limestone of Hartshill, Nuneaton.[1] The principal difference is that the angle at the apex of the dorsal portion of the Comley specimen is about 130° instead of 90°.

HYOLITHUS (ORTHOTHECA ?) sp. indet. *b*. (Pl. XXIV, fig. 35.)

A very different operculum from the same horizon as the last is referred somewhat doubtfully to the sub-genus *Orthotheca*. It is sub-triangular, has the nucleus situated near the ventral angle and the conical dorsal projection is very narrow, the angle at the apex being only about 45°. On each side of its boundary-lines two projections on the interior appear to indicate muscle attachments. The exterior has faint striæ of growth near the margin. The margin appears to be in one plane, and the plate when in place would be (on the whole) concave.

Locality and horizon for both opercula.—Comley, Lower Cambrian; from the *Protolenus* Limestone, horizon Ac_5.

[1] Cobbold, 1919, p. 150 & pl. iv, figs. 7–9.

Lapworthella, gen. nov.

Diagnosis.—Small, tapering, annulated shells of circular or sub-polygonal section, consisting of two layers, the inner one of medium thickness, the outer very thin and chitinous. Annulations formed by pronounced raised ridges encircle the tube, and divide it into sub-equal parts.

Type-species—*Lapworthella nigra*, sp. nov.

Localities and horizon.—Lower Cambrian, near the summit. Comley and Neve's Castle, both in Shropshire.

The genus appears to be intermediate between *Hyolithus* (*Orthotheca*) and *Salterella*, with certain resemblances to *Tentaculites*.

From *Orthotheca* it is distinguished by the character of the encircling ridges, which are quite different from striæ of growth.

The resemblance to *Tentaculites* consists in the form and disposition of the same encircling ridges.

The relations to *Salterella* are much closer. In size, curvature of shell, and frequent circularity of aperture the two genera have much in common. The differences consist in the structure of the shell and the form of the annulating ridges.

The generic characters of *Salterella* are thus given by Billings:

> 'small, slender, elongate-conical tubes, consisting of several hollow cones placed one within another, the last forming the chamber of habitation of the animal. The cross-section of the tube is circular or sub-triangular, and they are either straight or gently curved, the surface is concentrically or longitudinally striated.' (1861, vol. i, p. 17.)

In his description of the type-species *Salterella rugosa*, Billings states that the annulations are formed by the projecting edges of the successive cones, and Dr. Walcott's figures of the species [1] show this structure very clearly.

Other species referred to *Salterella* are (1) *S. pulchella* Billings,[2] (2) *S. curvata* Shaler & Fœrste,[3] and (3) *Serpulites maccullochi* Salter.[4]

In the first the structure of the tube has a tripartite arrangement; in *S. curvata* it is stated to be thick, but no indication is given of the shell-structure; in *Serpulites maccullochi* the tube appears to be very thick, but its structure is not described. Billings suggests (*op. jam cit.*), however, that *Salterella rugosa* 'must be closely allied to *S. maccullochi*,' and his generic reference for that species has been generally adopted.

In the absence of any detailed study of the shell-structure of the two last-named species, it may be left an open question whether they should continue to be referred to the genus *Salterella*.

[1] 1890, pl. lxxix, fig. 4.

[2] 1861, p. 18. Walcott's figures of *S. pulchella* (1890, pl. lxxix, figs. 5, 5 *a*–5 *e*) suggest that more than one species may be represented.

[3] Shaler & Fœrste, 1888, p. 34. [4] 1859, p. 381.

Prof. Charles Lapworth was the first to point out that the *Olenellus* and *Paradoxides* Zones were in contact in the Shropshire area, and he has also shown very great interest in the explorations conducted at Comley for the British Association. It seems, therefore, appropriate to dedicate a genus that marks, at least locally, the dividing-line between the Lower and Middle Cambrian to his honour.

LAPWORTHELLA NIGRA, sp. nov. (Pl. XXIV, figs. 1–6.)

Salterella (perhaps 2 spp.), Cobbold, 1909, Rep. Brit. Assoc. (Dublin, 1908) p. 235.
Salterella Cobbold, 1910, Q. J. G. S. vol. lxvi, p. 20.

Type-specimens [270, 267]; also [RR. 1221], Geological Survey collection.

Diagnosis.—Shell: a small, pyramidal or conical, curved tube, divided into from twelve to twenty annulations; rate of taper, variable, from 1 in 1·4 to 1 in 4·3 (equivalent apical angles 41° to 13°); aperture transverse, varying from sub-circular to sub-rhomboidal; apex sharp; shell-substance of two layers: (1) inner layer moderately thick, calcareous and annulated on the exterior by prominent ridges, which are at right angles to the curved axis of the tube, pass all round it, and are set at nearly uniform distances apart; (2) outer layer very thin, of black, chitinous (?) material, which passes over the transverse ridges giving them a sharp edge; interior of shell smooth, or slightly marked by annular lines of thickening corresponding to the transverse ridges. No septa or operculum have been observed.

Dimensions.—Lengths = 2 to 3 mm.; diameter of aperture = 2 to 1·5 mm.

The species is very variable: not only is there a considerable range in the apical angle, but the sectional form is not constant. Some specimens appear to be truly circular, others are more or less semicircular, and others again are sub-trapezoidal. There is also much variation in the spacing of the encircling ridges.

Localities and horizon.—Comley and Neve's Castle; from the *Lapworthella* Limestone, horizon Ad.

SALTERELLA Billings.

SALTERELLA (?) BELLA, sp. nov. (Pl. XXIV, fig. 33.)

Type-specimen [523].

Diagnosis.—Shell a small, tapering, curved tube with elliptical aperture, axes in the proportion of 1 to ·6, rate of taper 1 in 1·5, equivalent apical angle 40°; shell-substance calcareous, thick, and strong; exterior marked with numerous, delicate, impressed striæ of growth and from five to eight irregular constrictions; no radial striæ; apex not preserved.

Dimensions.—Height = 1·25 mm.; longer diameter of aperture = 1 mm.; length = 1·5 mm.

SALTERELLA (?) STRIATA, sp. nov. (Pl. XXIV, fig. 45.)

Type-specimen [139].

Diagnosis.—Shell a small, tapering, curved tube with elliptical aperture; axes in the proportion of 1 to ·6, rate of taper 1 in 1·8, equivalent apical angle 32°; shell-substance calcareous, thick, and strong; exterior marked with eight or more constrictions (which are reproduced on the interior) and numerous fine radiating striæ; no lines of growth seen.

Dimensions.—Height=2 mm.; diameter=1·7 mm.; length=3 mm.

Observations.—Owing to the absence of any obvious cone-within-cone structure such as characterizes the type-species *S. rugosa*, the reference of these two species to Billings's genus is made with reserve. The thick calcareous shell and bent conical form indicate a relationship with *S. curvata* and *Serpulites maccullochi* (see p. 359). On the other hand, *Salterella striata* has points of resemblance with *Helcionella* and *Scenella*.

Locality and horizon.—Comley, Lower Cambrian. Both species are found in the *Protolenus* Limestone, horizon Ac_5.

HYOLITHELLUS Billings.

HYOLITHELLUS MICANS Billings. (Pl. XXIV, figs. 19–21.)

Hyolithellus micans Billings, 1872, 'Canadian Naturalist' n. ser. vol. vi, p. 215.
Hyolithellus micans Billings, Walcott, 1886, U.S. Geol. Surv. Bull. 30, p. 142 & pl. xiv, figs. 2, 2 *a*–2 *e*.
Hyolithellus micans Billings, Shaler & Fœrste, 1888, Bull. Mus. Comp. Zool. Harvard, vol. xvi, p. 34 & pl. ii, fig. 23.
Hyolithellus micans Billings, Walcott, 1890, 10th Ann. Rep. U.S. Geol. Surv. p. 624 & pl. lxxix, figs. 1, 1 *a*–1 *e*.
Hyolithellus cf. *micans* Billings, Lapworth, 1891, Geol. Mag. p. 532.
Hyolithellus micans Billings, Matthew, 1899, Bull. Nat. Hist. Soc. New Brunswick, xviii, p. 192 & pl. ii, figs. 1 *a*–1 *d*.
Hyolithellus micans Billings, Matthew, 1899, Trans. Roy. Soc. Canada, vol. v, sect. 4, p. 109 & pl. vi, figs. 1 *a*–1 *d*.
Hyolithellus micans Billings, Grabau, Occ. Pap. Boston Nat. Hist. Soc. vol. iv, pt. 3, p. 658 & pl. xxxii, fig. 12.

Short lengths of tubes with black shining surfaces are of frequent occurrence at Comley, and, although they assume many aspects, there are no well-defined characters to separate them one from the other or from Billings's species. They occur at many horizons, ranging from Ab_5 in the Lower to Bb_1 in the Middle Cambrian. In section they are circular, the surface may be smooth, or annulated with lines or bands of growth; they are most frequently straight, but sometimes sinuous (fig. 20) or even strongly curved (fig. 19) and they show very slight traces of taper. The diameters vary from ·1 to 2·5 or even 3 millimetres.

In thin sections the tube is seen to consist of one thin layer of chitinous material, which must have been comparatively strong and resistant, for the specimens rarely show any sign of collapse or crushing.

Locality and horizon.—Comley. Lower and Middle Cambrian; from horizons Ac_1, Ac_2, Ac_3, Ac_4, Ac_5, Ad, Ba_1, Ba_2, Ba_3,

Bb_1: that is, from below the *Olenellus* Limestone to the representative of the *Paradoxides-tessini* Zone of Scandinavia.

HYOLITHELLUS MICANS, var. PALLIDUS nov. (Pl. XXIV, fig. 23.)

A form, which may be separated as a distinct variety, occurs at a comparatively low horizon in the Lower Cambrian. It has a truly circular section, a rather stronger rate of taper, and, so far as known, is always straight. The surface is grey and dull, not glistening; it shows slight traces of striæ of growth. The diameter varies from ·3 to 1·2 millimetres.

Locality and horizon.—Comley, Lower Cambrian; from the *Holmia* horizon Ab_3; also doubtfully from horizon Ab_2.

HYOLITHELLUS MICANS, var. ROBUSTUS nov. (Pl. XXIV, fig. 22.)

This variety is one of those forms that is easily distinguished when seen and handled, but the special characteristics are very difficult to describe in words.

It is separated from the more typical forms of *H. micans* by its usually larger diameter (3 to 5 millimetres), its more decided rate of taper (about 1 in 30), and in that it only occurs associated with a *Paradoxides* fauna.

The outer skin is thin (?), phosphatic, and usually grey; in addition, it frequently has a thick lining of calcite which, in one case, where the tube is 3 mm. in diameter, is as much as ·4 mm. thick, and simulates an inner shell. Whether this lining represents part of the original organism, or is a mineral deposit subsequent to its death cannot at present be determined.

Locality and horizon.—Comley, Middle Cambrian; from horizons Ba_1 of the *Paradoxides-œlandicus* Zone and Bb_1 at the base of the *Paradoxides-tessini* Zone.

HYOLITHELLUS (?) SINUOSUS, sp. nov. (Pl. XXIV, fig. 24.)

Type-specimen [1912].

This specific name is proposed for small, circular, phosphatic tubes which are curved in more than one plane, have a dull grey surface, and are not associated with any that can be referred to *H. micans*. Only two or three fragmentary specimens have been as yet found, and one of these shows distinct lines of growth, evenly spaced along the tube.

Locality and horizon.—The Cwms, near Comley, Lower Cambrian; from the greenish-grey sandstone, *Obolella-groomi* Beds, horizon Ab_1.

SALOPIELLA, gen. nov.

Diagnosis.—Small tubes with elliptical section and subparallel margins; shell-structure calcareous (?), thin, and formed of a number of closely-set, step-like annulations, which encircle the tube and are reproduced on the interior.

Genotype.—*S. obliqua*, sp. nov.

Locality and horizon.—Comley (Shropshire), Lower Cambrian.

These tubes agree with Holm's genus *Torelella* in their elliptical section and sub-parallel margins; but there is no trace of the phosphatic shell of that genus, and the wall of the tube is very different.

The external aspect recalls that of *Salterella*, but the elongate form of the tubes and the absence of any sign of the cone-within-cone structure of the shell preclude any reference to that genus.

SALOPIELLA OBLIQUA, sp. nov. (Pl. XXIV, figs. 18 *a*–18 *c*.)

Type-specimen [242].

Diagnosis.—Shell tubular, thin, slightly curved, and having a very slight taper; section elliptical, ratio of diameters 1 to ·55. Shell-substance calcareous (?); shell-structure consisting of a number of angular step-like corrugations which are spaced about 12 to the millimetre, pass obliquely round the tube, and are reproduced on the interior. One slope of these corrugations is nearly parallel to the axis of the tube, the other is very steeply inclined to it.

Dimensions.—Larger diameter = about ·6 mm.; greatest length seen = 3·5 mm.

Observations.—The type-material consists of an internal cast in calcite [212] and a partly internal, partly external cast in sandy limestone [231]. The shell appears to have been calcareous, for in the second specimen it has entirely disappeared, with no trace of any phosphatic material.

Locality and horizon.—Comley, Lower Cambrian; from the *Strenuella* Limestone, horizon Ac_4.

HELENIA Walcott, 1890.

HELENIA CANCELLATA, sp. nov. (Pl. XXIV, figs. 7 *a*–10.)

Helenia Cobbold, 1911, Q. J. G. S. vol. lxvii, p. 297.

Type-specimens [245, 246].

Diagnosis.—Shell: a flattened curved tube, tapering very gradually to a blunt, closed end; section, a narrow oval; shell-substance thin, phosphatic; exterior beautifully sculptured by two sets of impressed lines running obliquely across the shell and leaving minute, diamond-shaped projections between them.

Dimensions.—Diameter = about ·5 mm.; greatest length seen = 6 mm.

Observations.—Usually there is a longitudinal depression close to the concave margin—it does not reach the closed end, is not seen at all in one specimen, and is probably due to the collapse of the tube.

The type-species of the genus, *H. bella* Walcott,[1] is described as 'probably open at both ends'; it has but one set of diagonal lines. *H. granulata* Matthew[2] is described as having a minutely

[1] 1889, p. 39; and 1890, p. 610 & pl. lxxviii, figs. 4, 4 *a*–4 *b*.
[2] 1899 *a*, p. 192; 1899 *b*, p. 107 & pl. vi, figs. 7 *a*–7 *e*.

granular surface; it is larger, and tapers more rapidly than *H. cancellata.*

Locality and horizons.—Comley, Lower Cambrian; from the *Olenellus* Limestone, horizon Ac_2, the *Microdiscus-bellimarginatus* Limestone, horizon Ac_3, the *Protolenus* Limestone, horizon Ac_5, and the *Lapworthella* Limestone, horizon Ad.

VII. The Comley Gasteropoda.

Scenella Billings.

Scenella elevata, sp. nov. (Pl. XXIV, fig. 36.)

Type and only specimen [RR 1211, Geological Survey, Rhodes collection, 1892].

Diagnosis.—Shell patelliform with apex towards the anterior (?) end, depressed slightly below the highest point; aperture not seen, probably an ellipse; posterior and lateral slopes very slightly convex and inclined, anterior slope approaching the vertical; shell-substance calcareous, exterior with closely-set, impressed radiating lines, scarcely visible on the upper half of the shell, but strong towards the margins with the interspaces rounded; these are crossed by delicate concentric lines of growth and six or seven stronger lines, which near the apex tend to form constrictions, but in the remainder of the shell mark angular changes of curvature.

Dimensions.—Length = about 3·5 mm.; width = 3 mm.; height = 1·66 mm.

The species is referred to Billings's genus, on account of the absence of pronounced concentric rugosities, though in the depression of the apex it resembles *Helcionella.* It may be contrasted with Dr. Kiær's two species, *Scenella antiqua* and *Sc. depressa*,[1] from Tömten.

Locality and horizon.—Comley, Lower Cambrian; from the *Olenellus* Limestone, horizon Ac_2.

Helcionella Grabau & Shimer.

Helcionella cingulata, sp. nov. (Pl. XXIV, fig. 37.)

Type-specimen [827].

Diagnosis.—Shell patelliform, with elevated apex; aperture not known, but, as indicated by the cross-section, an elongated ellipse with axes in the ratio of 5 to 2; apex slightly curved over towards the anterior (?) end; shell-substance calcareous, with black, phosphatic, outer pellicle; exterior marked by concentric rounded fillets, set at even distances apart and separated by flat or slightly concave spaces about three times as wide as the fillets themselves.

Dimensions.—The only known specimen is fragmentary: it is 2 mm. in height and 4 in length.

[1] 1916, pp. 17, 18 & pl. ii, figs. 1, 1 *a*–1 *c*, 2 *a*–2 *c*.

Observations.—Similar concentric fillets are shown in Shaler & Fœrste's figure[1] of their species *Stenotheca curvirostra*, which is different in general form and has longitudinal striæ.

Locality and horizon.—Comley, Lower Cambrian; from the *Protolenus* Limestone, horizon Ac_5.

HELICONELLA OBLONGA, sp. nov. (Pl. XXIV, figs. 38 & 39.)

Stenotheca Cobbold, 1911, Q. J. G. S. vol. lxvii, p. 297.

Type-specimen [1316].

Diagnosis.—Shell patelliform, with apex strongly recurved; aperture oblong, with straight parallel sides and rounded ends; apex moderately sharp, bent down over the anterior (?) end to a height of about ·75 of the maximum. and at a point a little short of the anterior border; shell-substance thick and calcareous; exterior marked by very regular, step-like, concentric corrugations, retaining throughout the form of the aperture, also by numerous radiating thread-like raised lines spaced about five to the millimetre and increasing by interpolation; interior smooth, except for the reproduction of the external corrugations.

Dimensions of type-specimen.—Length=14 mm.; width=9·5 mm.; greatest height=4 mm.; height of apex=about 3 mm.

Observations.—This species occurs fairly plentifully in the matrix of the Middle Cambrian conglomerate of Comley Quarry, and is readily identified, even when poorly exposed, by the regularity of sculpture and the form of aperture. These features also serve to separate it from *H. rugosa* (Hall) and from other Comley forms of the genus.

The regularity of the step-like corrugations recall those shown in J. W. Salter's figure[2] of *Stenotheca cornucopia* from the Middle Cambrian of South Wales. That species is preserved in shale, and appears to have had a thin shell.

Locality and horizon.—Comley, Middle Cambrian, horizon Ba_1; from the Conglomerate of Comley Quarry, and from the same bed at Robin's Tump.

HELCIONELLA RUGOSA Hall, var. COMLEYENSIS nov. (Pl. XXIV, fig. 40.)

Metoptoma rugosa Hall, 1847, Pal. N. York, vol. i, p. 306 & pl. lxxxiii, figs. 6*a*–6*c*.
Stenotheca rugosa Hall, Billings, 1872, Canad. Nat. n. ser. vol. iii, p. 479.
Stenotheca rugosa Hall, Walcott, 1886, Bull. U.S. Geol. Surv. 30, p. 128 & pl. xii, figs. 1, 1 *a*–1 *e*.
Stenotheca rugosa, Hall, Walcott, 1890, 10th Ann. Rep. U.S. Geol. Surv. p. 617 & pl. lxxiv, figs. 1, 1 *a*–1 *e*.

Type for variety [1897].

This variety differs from the more typical forms of the species in the character of the encircling rugosities. The aperture is a wide ellipse, ratio of axes 1 to ·9; the concentric rugosities of

[1] Bull. Mus. Comp. Zool. Harvard, vol. xvi, No. 3, p. 30 & pl. i, fig. 8.
[2] 1872, Q. J. G. S. vol. xxviii, p. 180 & pl. vii, figs. 12–13.

growth are very irregular, varying in strength from one part of their course to another and running one into another, so that there are no well-defined step-like annulations; the radiating striæ are, on the other hand, quite regular: they increase by interpolation, and are spaced about seven to the millimetre.

Dimensions of largest specimens.—Length = 17 mm.; width = 15·5 mm.; greatest height = 7 mm.; height of apex = 4 mm.

Locality and horizon.—Comley, Lower Cambrian; from the *Olenellus* Limestone, horizon Ac_2, and from the *Callavia* Sandstone, horizon Ac_1.

Latouchella, gen. nov.

Diagnosis.—Shell small, calcareous, coiled or incipiently coiled so as to be isometrical about the median plane; aperture elongate, entire, not notched; whorls free, not in close or overlapping contact.

Type-species—*L. costata*, sp. nov.

Horizon.—Lower Cambrian.

The incipient coiling and elongate aperture are reminiscent of *Platyceras*, from which these shells differ in having the apex on the median plane.

In side view they approach some forms of *Helcionella*, particularly *H. paupera* Billings, but they are without encircling annulations or rugosities.

The absence of a notch in the apertural margin seems to preclude a reference to any of the Heteropod-like shells, such as *Pelagiella* Matthew, *Watsonella* Grabau, etc.

The external resemblance of *L. costata* to an immature ammonite is remarkable; there are, however, no indications of septa.

Latouchella costata, sp. nov. (Pl. XXIV, figs. 41 & 42.)

Type-specimen in the collection of the Rev. W. M. D. La Touche, of Wistanstow, Craven Arms.

Diagnosis.—Shell consisting of about one and a quarter whorls; aperture oval (ratio of diameters about 1 to ·5) and slightly campanulate; sides provided with six to eight or more elongate prominent ribs, swollen towards the convex margin of the shell, which they do not cross, and narrowing to disappear in the opposite direction, these are reproduced in the interior: whorls standing clear of one another in the internal cast, probably just touching one another in the complete shell. Dorsum narrowly rounded, but not keeled.

Dimensions of the larger specimen.—Apertural diameters $= 4 \times 2$ mm.; total length = 4·5 mm.; height = 2·5 mm.

Locality and horizon.—Comley, Lower Cambrian; from the *Olenellus* Limestone, horizon Ac_3, and from the *Protolenus* Limestone, horizon Ac_5.

LATOUCHELLA (?) STRIATA, sp. nov. (Pl. XXIV, figs. 43 & 44.)

Type-specimen [2655], other specimens [2659, 2661, 2662].

Diagnosis.—Shell coiled so as to make about three-quarters of a complete whorl; aperture an elongate egg-shaped oval, narrowing towards the dorsum; surface showing numerous, fine, impressed radiating striæ which strengthen as they approach the aperture, and of which some four or six are still more strongly marked along the dorsum. Dorsum narrowly rounded, but not keeled; no concentric lines of growth visible in the specimens.

Dimensions of largest specimen.—Apertural diameters=about 6×2 mm.; total length=about 6 mm.; height=5 mm.

This species is proportionately higher and narrower than *L. costata*, and the whorls are distinctly separated one from the other.

Localities and horizon.—Comley, Lower Cambrian, from the *Protolenus* Limestone, horizon Ac_5; also one specimen from the *Hyolithus* Limestone of Woodlands Quarry, Hartshill, Nuneaton [Birmingham University Collection].

VIII. THE COMLEY OSTRACODA.

LEPERDITIA Rouault.

LEPERDITIA (?) LENTIFORMIS, sp. nov. (Pl. XXIV, figs. 46 *a*–46 *c*.)

Type-specimen [Birmingham University Collection]. Three other specimens known.

Diagnosis.—General outline bean-shaped; anterior end shortly truncate; dorsal border gently convex for about two-thirds of the total length, then bending more rapidly and passing to the posterior rounded end in a line that is almost straight; ventral border one long fairly-regular curve from the truncate anterior to the posterior end; surfaces of both valves regularly convex, except near the anterior end, where there is a short ill-defined depression passing obliquely towards the ventral border; test thin, corneous, having the surface marked by a network of impressed lines, the interspaces being convex, and more or less elongate and parallel with the border.

Dimensions.—Length=11·5 mm.; depth=7 mm.; thickness of the two valves together=4 mm.

The general aspect of the species recalls that of *L. (?) dermatoides* Walcott,[1] which chiefly differs in having a very thin membranous and punctate test; that species has also a minute scar towards the posterior end, and a rather differently curved border.

In the type-specimen the two valves are in their natural position.

Locality and horizon.—Comley, Lower Cambrian; from the *Olenellus* Limestone, horizon Ac_2.

[1] 1890, p. 626 & pl. lxxx, figs. 1–1 *a*.

LEPERDITIA (?) DERMATOIDES Walcott (?).

Leperditia (?) dermatoides Walcott, 1890, 10th Rep. U.S. Geol. Surv. p. 626 & pl. lxx, figs. 1–1 *a*.

A single imperfect specimen [RR 1285] in the Geological Survey collection differs from *L. (?) lentiformis* in having a punctate test; it is also somewhat more convex and elongate. In these respects it simulates Walcott's species.

Locality and horizon.—Comley, Lower Cambrian; from the *Strenuella* Limestone, horizon Ac_4.

ESCASONA Matthew, 1902.

ESCASONA (?) spp. indet. (Pl. XXIV, figs. 47 & 48.)

Two forms suggest by their shape and convexity a reference to this genus, notwithstanding the fact that there is no sign of the ocular tubercle.

The two specimens figured [RR 1332 & RR 1335] are in the Geological Survey collection, and are too imperfect for closer identification. They probably represent two species.

Locality and horizon.—Comley, Lower Cambrian; from the *Olenellus* Limestone, horizon Ac_2.

BRADORIA Matthew.

BRADORIA (?) sp. indet. (Pl. XXI, figs. 28 *a*–28 *c*.)

A single specimen [14536] in the British Museum collection appears to belong to this genus. It is an internal cast, with some of the test adhering. In shape it is not unlike the figures of *Fordilla troyensis* Barrande, given by Dr. C. D. Walcott.[1] It has, however, a distinct marginal flat border, ventrally and at the two ends. There is no trace of an ocular tubercle near the hinge-line, but there is a tubercle low down towards the ventral anterior border. The body of the valve is marked with faint concentric lines, both inside and outside.

Dimensions.—Length = 2·5 mm.; width = 1·75 mm.; depth = ·7 mm.

Locality and horizon.—Comley, Lower Cambrian; from the *Olenellus* Limestone, horizon Ac_2.

IX. THE FAUNAS OF THE COMLEY HORIZONS AND THEIR ORDER OF APPEARANCE.

[Table II (p. 376) contains a list of all the fossils described or noted in this paper, together with the trilobites that have been recorded in previous communications; and also the horizons at which they have been found.]

The brachiopoda confirm and amplify the principal faunal divisions sketched out by me in 1911 (*b*, p. 296), and in my reports to the British Association. In some instances they lend considerable assistance in the correlation of the beds with those of other

[1] 1886, p. 125; and 1890, p. 615 & pl. lxxiii, figs. 2, 2 *a*–2 *c*.

areas; the pteropoda and gasteropoda, on the other hand, are, unfortunately, almost all new to science, but they serve to accentuate the divergences between the local faunas. The ostracoda, though well preserved, are very difficult of extraction without damage. Their general aspect is reminiscent of those described by Dr. G. F. Matthew (1902 & 1903) from the *Protolenus* and Etcheminian faunas and, so far as they go, these fossils help to confirm the opinion that the place of those two faunas is rather high up in the Lower Cambrian Series.

Lower Cambrian.

Horizon Aa. The Wrekin Quartzite.

Only one fragment of a corneous brachiopod has been found.

Horizon Ab_1. *Obolella* (?)-*groomi* Beds.

Micromitra (Paterina) phillipsi.	*Obolella (?) groomi.*
Micromitra (Paterina) rhodesi.	*Hyolithus strettonensis.*
Micromitra (Paterina) kingi.	*Hyolithellus sinuosus.*
Walcottina lapworthi.	Certain ovoid and elongate bodies that have been calcareous, and show only vague traces of organic origin.[1]
Walcottina elevata.	

Micromitra (P.) phillipsi and *Obolella (?) groomi* are found in the Malvern Quartzite and Hollybush Sandstone, while *Hyolithus strettonensis* may possibly be identical with *H. primævus* Groom of the same group.

On physical evidence Dr. C. Callaway correlated the sandstones of Comley with the Malvern Hollybush Sandstone; the fauna as enumerated above tends to prove that his correlation was, at least in part, correct.

Horizon Ab_2.

Hyolithus de geeri (?), *Hyolithellus micans* var. *pallidus*, and tracks on the surfaces of the flaggy beds.

Horizon Ab_3. *Holmia* Sandstone.

Holmia (?) sp. indet., *Hyolithellus micans* var. *pallidus*.

Horizon Ab_4.

Small and obscure ostracoda, gen. et sp. indet.

Horizon Ac_1. *Callavia* Sandstone.

Micromitra (Paterina) labradorica.	*Microdiscus attleborensis.*
Obolella atlantica var. *comleyensis.*	*Callavia callavei.*
Hyolithus sp. indet.	*Wanneria (?)* sp. nov.
Hyolithellus micans.	*Callavia cobboldi* Raw MS. (?).
Helcionella rugosa var. *comleyensis.*	

The relation of this fauna with that of other horizons is discussed below (p. 370).

Horizon Ac_2. *Olenellus* Limestone.

The *Olenellus* Limestone was the first horizon in the Comley area to yield any recognizable Lower Cambrian fossils, and naturally becomes a stratigraphical and palæontological datum to which other horizons may be referred. The complete fauna, so far as at present known, is tabulated below (p. 370).

[1] Cobbold, 1914, p. 486; and 1916, p. 118.

THE FAUNA OF THE *OLENELLUS* LIMESTONE OF COMLEY.[1]

Micromitra (Paterina) labradorica.
Micromitra (Paterina) minor.
Micromitra (Paterina) minor var. *gibba.*
Obolus parvulus.
Obolella atlantica var. *comleyensis.*
Hyolithus (Orthotheca) compressus.
Hyolithellus micans.
Helenia cancellata.
Scenella elevata.
Helcionella rugosa var. *comleyensis.*
Latouchella costata.
Leperditia (?) dermatoides (?).
Leperditia (?) lenticularis.
Escasona (?) spp. indet.
Bradoria (?) sp. indet.
Microdiscus annio.
Microdiscus attleborensis.
Micmacca (?) ellipsocephaloides.
Micmacca (?) ellipsocephaloides var. *senior.*
Micmacca (?) ellipsocephaloides var. *spinosa.*
Micmacca (?) ellipsocephaloides var. *strenuelloides.*
Micmacca (?) parvula.
Callavia callavei.
Callavia cf. *callavei.*
Callavia cartlandi.

There are obvious connexions between this fauna and that immediately below. *Micromitra labradorica*, *Obolella atlantica* var. *comleyensis*, *Helcionella rugosa* var. *comleyensis*, *Microdiscus attleborensis*, and *Callavia callavei* have already appeared in Ac_1, from which, however, the five forms of *Micmacca*, as well as the less frequent other fossils, are all absent, and one or more species of the Mesonacidæ, not appearing in the *Olenellus* Limestone, are present.

On comparing the Ac_2 fauna with those above it, there is a similar connexion observable, and to a considerable extent through the same species, but *Micmacca* is absent in the superior horizons, as also is *Microdiscus attleborensis*, their places being taken in horizon Ac_3 by *Strenuella pustulata* and *Microdiscus bellimarginatus*.

The faunas of the two next higher horizons, Ac_4 and Ac_5, are connected with the datum-fauna Ac_2 by *Micromitra labradorica*, *Obolus parvulus*, *Helenia cancellata*, *Latouchella costata*, and also by numerous fragments referred with reserve to *Callavia callavei*. Notwithstanding this connexion, the faunas of the *Strenuella* and the *Protolenus* Limestones (Ac_4 & Ac_5, see p. 371) are very distinct from those below and also one from the other. In Ac_4 occur three species of *Strenuella*, *Microdiscus lobatus*, *M. speciosus*, *Lingulella viridis*, *Obolella atlantica* var. *transversa*, *Hyolithus (Orthotheca) bayonet* var. *striata*, and *Salopiella obliqua*, none of which have been seen before; and in Ac_5 occur two species of *Protolenus*, two of *Mohicana*, *Microdiscus comleyensis*, *Hyolithus crassus*, *H. sculptilis*, *H. (O.) bayonet*, *Salterella (?) bella*, *S. (?) striata*, *Latouchella striata*, and *Helcionella cingulata*, all of which are confined to the horizon. *Strenuella* has entirely disappeared, as also has *Obolella atlantica*.

NOTE.—In the foregoing paragraphs all mention of *Hyolithellus micans* has been omitted, in order to avoid repetition. Forms referred to this species

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[1] In Cobbold, 1911 *b*, p. 298, this fauna was tabulated under the title '*Helena* Group.' A specimen has now been found of the pygidium then assigned to *Microdiscus helena* Walcott, attached, with three thoracic segments, to a cephalon then referred to *Ptychoparia (?) attleborensis* Shaler & Fœrste. The name *Helena* is, therefore, now abandoned.

occur in all the Lower Cambrian horizons Ac_4 to Ad, and also in the Middle Cambrian horizons Ba_1, Ba_2, Ba_3, and Bb_1 : that is, throughout the whole of the *Protolenus-Callavia* Fauna and of the *Paradoxides-ölandicus* Zone, and in the *Paradoxides-tessini* Zone.

The fragments assigned to *Callavia*, together with *Helenia cancellata* and the connexions between the individual faunas of horizons Ac_1 to Ac_5, serve to link them into one group, which has been called the *Protolenus-Callavia* Fauna [1] of Comley.

Of the species recorded, the following are found or represented in the Lower Cambrian of the Atlantic Province of North America, a considerable proportion being included in Dr. Matthew's *Protolenus* and Etcheminian Faunas.

Species of the *Protolenus-Callavia* Fauna of Comley (Horizons Ac_1 to Ac_5) which are represented in the Atlantic Province of North America :—

Micromitra (Paterina) labradorica.
Obolella atlantica var. *comleyensis.*
Obolella atlantica var. *transversa.*
Hyolithus (Orthotheca) bayonet.
Hyolithellus micans.
Helenia cancellata.
Helcionella rugosa var. *comleyensis.*
Leperditia (?) dermatoides.
Escasona (?) sp.
Bradoria (?) sp.
Microdiscus annio.
Microdiscus attleborensis.
Microdiscus bellimarginatus.
Microdiscus lobatus.
Microdiscus speciosus.
Strenuella platycephala.
Strenuella salopiensis.
Protolenus latouchei.
Micmacca (?) ellipsocephaloides var. *spinosa.*
Callavia callavei.
Wanneria (?) sp.

Horizon Ac_4. The *Strenuella* Limestone of Comley.[2]

Obolella atlantica var. *transversa.*
Lingulella viridis.
Hyolithus (Orthotheca) bayonet var. *striatus.*
Hyolithellus micans.
Salopiella obliqua.
Microdiscus lobatus.
Microdiscus speciosus.
Strenuella parva.
Strenuella platycephala.
Strenuella salopiensis.
Callavia cf. *callavei* (fragments).

The relations between this fauna and those of contiguous horizons are discussed above (p. 370).

Horizon Ac_5. *Protolenus* Limestone.

Micromitra (Paterina) labradorica.
Obolus parvulus.
Lingulella viridis.
Hyolithus crassus.
Hyolithus sculptilis.
Hyolithus (Orthotheca) bayonet.
Salterella (?) bella.
Salterella (?) striata.
Hyolithellus micans.
Helenia cancellata.
Helcionella cingulata.
Latouchella costata.
Latouchella striata.
Microdiscus comleyensis.
Microdiscus lobatus.
Microdiscus speciosus.
Protolenus latouchei.
Protolenus morpheus.
Mohicana clavata.
Mohicana lata.
Callavia cf. *callavei* (fragments).

For discussion of the relationship of this fauna to those below, see above (p. 370).

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[1] Cobbold, 1911 *b*, p. 297.

[2] The faunas of horizons Ac_4 and Ac_5 were combined under the one heading '*Lobatus* Group' in Cobbold, 1911 *b*, p. 297.

Horizon Ad. *Lapworthella* Limestone.

The fauna of the *Lapworthella* Limestone, Ad, is as follows:—

Species.	Remarks.
Acrothyra cf. *sera*	Confined to this horizon, but represented by a near ally, *A. comleyensis*, in the *Paradoxides* Beds.
Lapworthella nigra	Confined to this horizon.
Hyolithellus micans......	Ubiquitous, both above and below.
Hyolithellus micans var. *robustus*.	Now found for the first time, and passing up into the *Paradoxides* Beds.
Helenia cancellata	Found in the Lower Cambrian, from Ac_2, but not above this horizon.
Certain trilobitic (?) fragments, with characteristic tuberculate surface.	Found also in the *Protolenus* Limestone, but not in the *Paradoxides* Beds.

The fauna seems to indicate the incoming of a change from Lower to Middle Cambrian. On balance it must be classed with the Lower Cambrian, and the physical evidence points in the same direction.[1]

Note.—A collection made by Mr. J. Rhodes in 1892, at Neve's Castle in the Wrekin district, for the Geological Survey, contains a number of specimens of a black rock having the lithological characteristics of the *Lapworthella* Limestone, and yielding *Acrothyra* cf. *sera*, *Lapworthella nigra*, and *Hyolithellus micans* in similar abundance. The *Paradoxides* and *Olenellus* faunas are known to be in juxtaposition in this area; but the section at the junction is not open, and it is consequently impossible to say whether the *Lapworthella* Limestone of Neve's Castle stands in the same relation to the other beds as it does at Comley.

Middle Cambrian.

Horizon Ba_1. *Paradoxides-groomi* Grits.

Acrothyra comleyensis.	*Conocoryphe emarginata* var. *longifrons.*
Hyolithellus micans.	*Dorypyge lakei.*
Hyolithellus micans var. *robustus.*	*Paradoxides groomi.*
Helcionella oblonga.	*Paradoxides* spp. indet., 3 species.

The deposits grouped in this horizon consist of three lithological divisions:—(A) An impersistent layer of phosphatic gritty material which adheres to the surface of the *Lapworthella* Limestone, and is rarely more than 1 inch thick; (2) a conglomeratic deposit containing numerous blocks of pre-existing limestone and clots of contemporaneous calcareous material; (3) a coarse grit, with a few similar calcareous clots and blocks of pre-existing limestone.

Horizon Ba_2.

Obolus sp. indet. *a.*	*Hyolithellus micans.*
Acrotreta sp. indet. *b.*	

The paucity of this fauna is attributed to the crushing of the shale-beds and the absence of good exposures.

[1] Cobbold, 1916, pp. 119, 120.

Horizon Ba_3. *Dorypyge-lakei* Flags.

Acrotreta socialis.	*Hyolithellus micans.*
Acrothyra comleyensis.	*Dorypyge lakei.*

The three horizons Ba_1, Ba_2, & Ba_3 may be correlated[1] with the *Paradoxides-œlandicus* Zone of Scandinavia, in which *A. socialis* is found typically, though it is also recorded from higher zones.

Horizon Bb_1. *Paradoxides-intermedius* Grits.

Billingsella sp. indet.	*Ptychoparia (Liostracus) lata.*
Hyolithellus micans var. *robustus.*	*Ptychoparia (Liostracus) dubia.*
Microdiscus punctatus.	*Agraulos* cf. *quadrangularis.*
Conocoryphe æqualis.	*Strenuella (?)* spp. indet.
Conocoryphe bufo.	*Dorypyge reticulata.*
Conocoryphe impressa.	*Paradoxides intermedius.*

The relation of this fauna to that of the *Paradoxides-tessini* Beds of Scandinavia (near the *C. exsulans* sub-zone) and to the *Paradoxides-hicksi* Zone of South Wales has already been discussed.[2]

Horizon Bb_2.

Obolus sp. indet. *b.*	*Acrotreta* sp. indet. *c.*

Horizon Bb_3.

No exposures available. By position it is inferred that the *Hartshillia* fauna,[3] Horizons E_1, E_2, E_3 of the Nuneaton area, if present at Comley, should come here.

Horizon Bb_4. *Paradoxides-rugulosus* Sandstone.

Lingulella ferruginea.	*Paradoxides rugulosus.*
Lingulella sp. indet.	

Paradoxides rugulosus suggests a reference to the Lower *Davidis* Fauna of Nuneaton (Horizons F_1, F_2 of Illing).[4]

Horizon Bb_5. *Paradoxides-davidis* Flags.

Lingulella ferruginea.	*Conocoryphe* sp. indet.
Acrotreta sagittalis.	*Ptychoparia (Liostracus) pulchella.*
Billingsella cobboldi.	*Ptychoparia (Liostracus) dubia.*
Billingsella lindstrœmi var.	*Agraulos (?) holocephalus.*
Microdiscus cf. *punctatus.*	*Agraulos* cf. *quadrangularis.*
Agnostus fallax.	*Paradoxides davidis.*

This fauna may be compared with those of the *Paradoxides-davidis* horizons of Scandinavia, South Wales, and Nuneaton.

Horizon Bc. *Billingsella* Beds.

Micromitra sp. indet.	*Acrotreta sagittalis.*
Obolus cf. *schmalenseei.*	*Acrotreta schmalenseei* var. *matleyi.*
Obolus gibbosus.	*Acrotreta* sp. indet. *a.*
Obolus (?) linnarssoni.	*Billingsella lindstrœmi* var. *salopiensis.*
Acrothele coriacea.	

Eight of these nine species are either identical with, or closely related to, species cited by Dr. C. D. Walcott as occurring in the *Paradoxides-forchammeri* Zone of Scandinavia, with which the Comley *Billingsella* Beds are consequently correlated.

[1] Cobbold, 1913, p. 43.
[2] Cobbold, 1913, pp. 39, 40.
[3] V. C. Illing, 1915, p. 399.
[4] 1915, p. 400.

Upper Cambrian.

Horizon Ca. *Orusia* Shales.

Acrothele coriacea.	Trilobite-fragments, suggesting one
Orusia lenticularis.	or more species of the Olenidæ.

Orusia lenticularis occurs plentifully in thin calcareous or mudstone-beds intercalated with shales and, sporadically, in the shale itself. Prof J. C. Moberg, writing [1] of the *Orusia-lenticularis* Beds of Sweden, says, 'not infrequently we find this brachiopod by itself crowding entire limestone-bands. It occurs very often together with *Parabolina spinulosa*, especially in the shales.' The conclusion that Horizon Ca should be grouped with the Upper Cambrian seems fully borne out.

Horizon Cx.

This designation is used to include the beds which yielded '*Lingulella nicholsoni* and the Shineton graptolites' to Dr. C. Callaway.[2] His exposure has not been identified. It was situated some 500 yards, more or less, to the north-east of Comley Quarry.

X. General Summary.

As a result of this study of the Cambrian faunas of Comley, the strata of the Lower Cambrian fall into eleven local divisions, Aa, Ab_1, Ab_2, Ab_3, Ab_4, Ac_1 Ac_2, Ac_3, Ac_4, Ac_5, and Ad.

The first defined fauna to invade the area was one comparable with, and in extension of, that found in the quartzite and Hollybush Sandstone of the Malvern Cambrian area. From it the genus *Walcottina*, intermediate between *Mickwitzia* and *Kutorgina*, is now described.

A second incoming fauna is possibly foreshadowed by a few forms in Ab_3, which include a species of *Holmia* or a near ally. For want of brachiopoda and other fossils this fauna cannot be closely defined.

A third faunal group, the *Protolenus-Callavia* Fauna, appears in Horizons Ac_1, Ac_2, Ac_3, Ac_4, Ac_5, and includes a very considerable number of species that find their analogues in the Lower Cambrian of North America. This group is separable into five faunas, not necessarily of equal value, but sufficiently distinct to be worthy of separate record. The three lower faunas in horizons Ac_1, Ac_2, Ac_3 are characterized by an abundance of fragments referable to *Callavia callavei* and other related species, and are separated by the changes that are noted among the smaller trilobites, brachiopods, etc. The two higher faunas in horizons Ac_4, Ac_5, are characterized by plentiful remains of *Strenuella* in Ac_4, and of *Protolenus* in Ac_5. Two genera among the pteropoda and one among the gasteropoda are now described for the first time.

Immediately above the *Protolenus* Limestone the *Lapworthella* Limestone, horizon Ad, occurs: this appears to contain a fauna

[1] 1910, p. 176.
[2] 1877, p. 659.

somewhat intermediate between those of the Lower and the Middle Cambrian, but still to be classed with the former. As it is also recorded from Neve's Castle in the Wrekin district, where the Lower and the Middle Cambrian are again in juxtaposition, this bed and its fauna seem of interest as a possible index of the dividing-line between the two formations. Further evidence of a transition, if such ever existed in the district, is lost by reason of the unconformity that ushers in the Paradoxidean fauna, which only arrived after a considerable interval.

The Middle Cambrian faunas have already been indicated in previous publications by me; the *Paradoxides-œlandicus* fauna in horizons Ba_1, Ba_2, and Ba_3; the *P.-tessini* fauna in horizon Bb_1, and probably higher zones; the *P.-davidis* fauna in horizons Bb_1 and Bb_5.

The brachiopoda now prove the presence of a fauna of *Paradoxides-forchammeri* age in horizon Bc, and the Upper Cambrian age of the *Orusia* Shales, horizon Ca, at the summit of the sandstone series of Comley.

Certain points of, perhaps, minor importance result from the detailed study of the brachiopoda. The genus *Acrothyra* appears in the district at the summit of the Lower Cambrian deposits, and its range is extended into the Middle Cambrian. The specimens are in such excellent preservation that it has been possible to determine the forms of the visceral cavity in at least four stages of growth. *Micromitra (Paterina) labradorica* exhibits some features of the growth of the adult shell, and was preceded in time in this district by *M. (P.) phillipsi.* The specimens of *Obolella atlantica* in two varieties show the internal characters distinctly.

I could not have undertaken the study of the Comley brachiopoda without the help of Dr. C. D. Walcott's monograph, which has served as text-book, bibliography, stratigraphical guide, and work of reference, all in one, and I desire to acknowledge the very great assistance which I have received from that comprehensive work. I am also most grateful to Dr. Walcott for the loan and gift of some American specimens.

I am also further indebted to Dr. C. A. Matley for the notes on the brachiopoda of the *Paradoxides* Beds of Comley (1911); they were almost my first lesson in the study of this group of fossils.

At the outset of the excavation work at Comley, Dr. T. T. Groom very kindly examined some of the pteropoda, and his preliminary assistance was of considerable value. Grateful thanks are also due and tendered to Prof. W. J. Sollas, for the opportunity of studying the specimens from Malvern that are in the Oxford Museum. Last, but by no means least, I owe an ever-increasing debt of gratitude to the late Prof. Charles Lapworth for much kind advice as to the scope of this paper and for encouragement throughout its preparation.

Table II.—The Faunas of the Comley Horizons.

Index-letters	Aa.	Ab$_1$.	Ab$_2$.	Ab$_3$.	Ab$_4$.	Ac$_1$.	Ac$_2$.	Ac$_3$.	Ac$_4$.	Ac$_5$.	Ad.	Ba$_1$.	Ba$_2$.	Ba$_3$.	Bb$_1$.	Bb$_2$.	Bb$_3$.	Bb$_4$.	Bb$_5$.	Bc.	Ca.	Cx.
Brachiopoda.																						
Micromitra sp. indet. (p. 328)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×		
Micromitra (Paterina) phillipsi Holl (p. 329) ...	...	×																				
Micromitra (P.) rhodesi, sp. nov. (p. 330)	...	×																				
Micromitra (P.) kingi, sp. nov. (p. 330)	...	×																				
Micromitra (P.) labradorica Billings (p. 332) ...	...	...	...	...	...	×	×	×	...	×												
Micromitra (P.) minor, sp. nov. (p. 333)	...	...	...	...	...	...	×															
Micromitra (P.) minor, var. *gibbosa*, nov. (p. 334)	...	...	...	...	...	...	×															
Walcottina lapworthi, gen. et sp. nov. (p. 336) .	...	×																				
Walcottina elevata, gen. et sp. nov. (p. 337)	...	×																				
Obolus parvulus, sp. nov. (p. 338)	...	...	...	...	...	...	×	×	...	×												
Obolus (?) cf. *schmalenseei* Walcott (p. 340)......	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×		
Obolus (?) gibbosus, sp nov. (p. 339).....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×		
Obolus (?) linnarssoni, sp. nov. (p. 338)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×		
Obolus (?) sp. indet. *a* (p. 340)	...	...	...	...	...	...	...	...	...	...	...	...	×									
Obolus (?) sp. indet. *b* (p. 340)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×						
Lingulella ferruginea Salter (p. 342)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×			
Lingulella nicholsoni Callaway (p. 341)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×
Lingulella viridis, sp. nov (p. 341)........	...	...	...	...	...	...	...	...	...	×	×											
Lingulella sp. 'a small oval form' Matley (p. 342)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×				
Obolella atlantica Walcott, var. *comleyensis* nov. (p. 342)	...	...	...	...	...	×	×	×														
Obolella atlantica Walcott, var. *transversa* nov. (p. 344)	...	...	...	...	...	...	...	...	×													
Obolella (?) groomi Matley (p. 345)	...	×																				
Acrothele coriacea Linnarsson (p. 345)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×	×	
Acrotreta sagittalis Salter (p. 346)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×		

Acrotreta schmalenseei Walcott, var. *matleyi* nov. (p. 346)	...	...	...	...	...	...	...	...	...	...	...	...	...	..	...	..	...	...	?	×	
Acrotreta socialis Seebach (p. 347)	...	...	...	...	...	...	...	...	...	...	...	...	...	×							
Acrotreta sp. indet. *a* (p. 347)	...	...	...	...	...	...	...	...	...	...	...	...	...	..	...	...	...	...	...	×	
Acrotreta sp. indet. *b* (p. 348)	...	...	...	...	...	...	...	...	...	...	...	...	×								
Acrotreta sp. indet. *c* (p. 348)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×					
Acrothyra comleyensis, sp. nov. (p. 348)	...	...	...	...	...	...	..	...	...	...	...	×	...	×							
Acrothyra cf. *sera* (Matthew) Walcott (p. 350)	...	..	...	...	...	...	...	...	...	...	×										
Billingsella lindstrœmi, var. *salopiensis* Matley (p. 353)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×	
Billingsella cobboldi Matley (p. 353)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..	..	...	×		
Billingsella sp. indet. (p. 354)	..	...	...	...	...	...	...	...	...	...	...	..	...	...	×						
Orusia lenticularis Wahlenberg (p. 354)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×
Pteropoda.																					
Hyolithus crassus sp. nov. (p. 354)	...	...	...	...	...	...	...	...	...	×											
Hyolithus sculptilis, sp. nov. (p. 356)	...	...	...	...	...	...	...	...	...	×											
Hyolithus strettonensis, sp. nov. (p. 355)	...	×																			
Hyolithus strettonensis, var. *brevis* nov. (p. 355)	...	×																			
Hyolithus (*Orthotheca*) *bayonet* Matthew (p. 357)	...	...	...	...	...	...	...	...	...	×											
Hyolithus (*O.*) *bayonet*, var. *striatus* nov. (p. 357)	...	...	...	...	...	...	...	...	×												
Hyolithus (*O.*) *compressus*, sp. nov. (p. 357)	...	...	...	...	...	...	×														
Hyolithus (*O.*) *de geeri* Holm (?) (p. 358)	...	...	×																		
Lapworthella nigra, gen. et sp. nov. (p. 360)	...	...	...	...	...	...	...	...	...	...	×										
Salterella (?) bella, sp. nov. (p. 360)	...	...	...	...	...	...	...	...	...	×											
Salterella (?) striata, sp. nov. (p. 361)	...	...	...	...	...	...	...	...	...	×											
Hyolithellus micans Billings (p. 361)	...	...	...	...	...	×	×	×	×	×	×	×	×	×	×						
Hyolithellus micans, var. *pallidus* (p. 362)	...	...	×?	×																	
Hyolithellus micans, var. *robustus* nov. (p. 362)	...	...	...	...	...	...	...	...	...	...	...	×	...	...	×						
Hyolithellus (?) sinuosus, sp. nov. (p. 362)	...	×																			
Salopiella obliqua, gen. et sp. nov. (p. 363)	...	...	...	...	...	...	...	...	×												
Helenia cancellata, sp. nov. (p. 363)	...	...	...	...	...	...	×	×	×	×	×										

The Faunas of the Comley Horizons (*continued*).

Index-letters	Aa.	Ab_1.	Ab_2.	Ab_3.	Ab_4.	Ac_1.	Ac_2.	Ac_3.	Ac_4.	Ac_5.	Ad.	Ba_1.	Ba_2.	Ba_3.	Bb_1.	Bb_2.	Bb_3.	Bb_4.	Bb_5.	Bc.	Ca
Gasteropoda.																					
Scenella elevata, sp. nov. (p. 364) ...	...	...	...	...	...	...	×														
Helcionella cingulata, sp. nov. (p. 364) ...	...	...	...	...	...	...	...	× ?	...	×											
Helcionella oblonga, sp. nov. (p. 365) ...	...	...	...	...	...	...	...	...	...	...	...	×									
Helcionella rugosa Hall, var. *comleyensis* nov. (p. 365) ...	...	...	...	...	...	×	×														
Latouchella costata, gen. et sp. nov. (p. 366) ...	...	...	...	...	...	...	×	...	...	×											
Latouchella (?) striata, gen. et sp. nov. (p. 367).	...	...	...	...	...	...	...	...	...	×											
Ostracoda.																					
Leperditia (?) lentiformis, sp. nov. (p. 367) ...	..	...	...	...	...	...	×														
Leperditia (?) dermatoides Walcott (?) (p. 368) .	...	...	...	...	...	...	×														
Escasona (?) spp. indet. (p. 368) ...	...	...	...	...	...	...	×														
Bradoria (?) sp. indet. (p. 368) ...	...	...	...	...	...	...	×														
Trilobita.																					
Microdiscus annio [1] Cobbold ...	. .	...	...	...	...	...	×														
Microdiscus attleborensis [1] Shaler & Fœrste ...	...	...	...	...	...	×	×														
Microdiscus bellimarginatus Shaler & Fœrste ...	...	...	...	...	...	...	...	×													
Microdiscus comleyensis Cobbold ...	...	...	...	...	...	...	...	...	...	×											
Microdiscus lobatus Hall ...	...	...	...	...	...	...	...	...	×	×											
Microdiscus punctatus Salter ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×						
Microdiscus cf. *punctatus* Salter ...	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×		
Microdiscus simplex Cobbold MS. ...	...	...	...	...	..	...	...	...	...	...	...	×									
Microdiscus speciosus Ford ...	...	...	...	..	...	...	...	...	×	×											
Agnostus fallax Linnarsson ...	...	...	...	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×		
Conocoryphe emarginata Linnarsson, var. *longifrons* Cobbold ...	...	...	...	...	...	...	...	...	...	...	...	×									
Conocoryphe æqualis Linnarsson ...	...	...	...	...	...	. .	...	...	...	...	...	...	...	...	×						

Conocorypne ovato Hicks	...	...	...	...	...	...	...	...	...	...	...	...	...	×						
Conocoryphe (*Liocephalus*) *impressa* Linnarsson.	...	...	...	...	...	...	...	...	...	...	...	...	...	×						
Ptychoparia (*Liostracus*) *dubia* Cobbold	...	...	...	...	...	...	.	...	...	...	...	...	...	×	...	...	...	×		
Ptychoparia (*Liostracus*) *lata* Cobbold	...	...	...	...	...	...	...	...	...	...	...	...	...	×						
Ptychoparia (*Liostracus*) *pulchella* Cobbold	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×		
Agraulos cf. *quadrangularis* Hall & Whitfield	...	...	...	...	...	...	...	...	...	...	...	.	...	×	...	...	...	×		
Agraulos (?) *holocephalus* Matthew	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×		
Strenuella parva [2] Cobbold	...	...	...	...	...	...	...	×												
Strenuella platycephala [2] Cobbold	...	...	...	...	...	...	...	×												
Strenuella pustulata [2] Cobbold	...	...	...	...	...	...	×													
Strenuella salopiensis Cobbold	...	...	...	...	...	...	...	×												
Strenuella spp. indet. Cobbold	...	...	...	...	...	...	...	...	...	...	...	...	...	×						
Protolenus latouchei Cobbold	...	...	...	...	...	...	...	...	×											
Protolenus morpheus Cobbold	...	...	...	...	...	...	...	...	×											
Micmacca (?) *ellipsocephaloides* Cobbold	...	...	...	...	...	×														
Micmacca (?) *ellipsocephaloides*, var. *senior* Cobbold	...	...	...	...	...	×														
Micmacca (?) *ellipsocephaloides*, var. *spinosa* Cobbold	...	...	...	...	...	×														
Micmacca (?) *ellipsocephaloides*, var. *strenuelloides* Cobbold	...	...	...	...	...	×														
Micmacca (?) *parvula* Cobbold	...	...	...	...	...	×														
Mohicana clavata Cobbold	...	...	...	...	...	...	...	...	×											
Mohicana lata Cobbold	...	...	...	...	...	...	...	...	×											
Dorypyge lakei Cobbold	...	...	...	...	...	...	...	...	...	...	×	...	×							
Dorypyge reticulata Cobbold	...	...	...	...	...	...	...	...	...	...	...	...	...	×						
Paradoxides davidis Salter	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×		
Paradoxides groomi Lapworth	...	...	...	...	...	...	...	...	...	...	×									
Paradoxides intermedius Cobbold	...	...	...	...	...	...	...	...	...	...	...	...	...	×						
Paradoxides rugulosus Corda	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×			
Paradoxides spp. indet. Cobbold	...	...	...	...	...	...	...	...	...	...	×									
Callavia callavei [3] Lapworth	...	...	...	...	×	×														
Callavia cf. *callavei* Lapworth, fragments	...	...	...	...	×	×	×	×	×											
Callavia cartlandi Raw MS., Walcott	...	...	...	...	...	×														
Callavia cobboldi Raw MS., Cobbold	...	...	...	...	× ?	...	×													
Holmia (?) sp. indet.	...	...	×																	
Wanneria (?) sp. indet.	...	...	...	...	×															

[1] These two *Microdisci* were described (1910) under *Ptychoparia (?)*. [2] These three *Strenuellæ* were described (1910) under *Anomocare*.
[3] *C. callavei* is found typically in Ac_2. Fragments assigned to the species abound in all the horizons marked.

EXPLANATION OF PLATES XXI–XXIV.

[The numerals in brackets are those attached to the specimens. Those with the letters RR before them refer to specimens collected by Mr. Rhodes for the Geological Survey. The name 'King' before a number indicates that the specimens had been collected by Mr. Wickham King, and presented by him to Mr. Rhodes's collection. A few specimens belong to the British Museum, and all others are from the collection for the British Association, which is in process of being deposited in the Sedgwick Museum, Cambridge.]

Plate XXI.

Micromitra (*Paterina*) *phillipsi* Holl, sp., × 4, see p. 329; horizon Ab_1.

Fig. 1. Ventral valve, with lateral view [RR 1472].
2. Do. do. with lateral and posterior views [RR 1467].
3. Do. do. internal cast, with lateral view [2334].

Micromitra (*Paterina*) *rhodesi*, sp. nov., × 4, see p. 330; horizon Ab_1.

Fig. 4. Type-specimen, ventral valve; *a*, summit view; *b*, posterior view; *c*, lateral view [RR 1473].
5. Ventral valve, alate form, from a squeeze of an external cast in soft sandstone [2271].
6. Ventral valve with lateral view, shell somewhat flattened and impressed with sand-grains, apex broken, revealing the thickness of shell [RR 1471].

Micromitra (*Paterina*) *kingi*, sp. nov., × 4, see p. 330; horizon Ab_1.

Fig. 7. Type-specimen, ventral valve with lateral view [King 2].
8. Ventral valve; *a*, summit view; *b*, posterior view, showing pseudodeltidium [King 2].

Micromitra sp., × 4, see p. 330; horizon Ab_1.

Fig. 9. Dorsal valve, with lateral and posterior views, associated with the previous specimens, shell exfoliated [RR 1465].

Micromitra (*Paterina*) *labradorica* Billings, × 4, see p. 332; horizons Ac_1 to Ac_5.

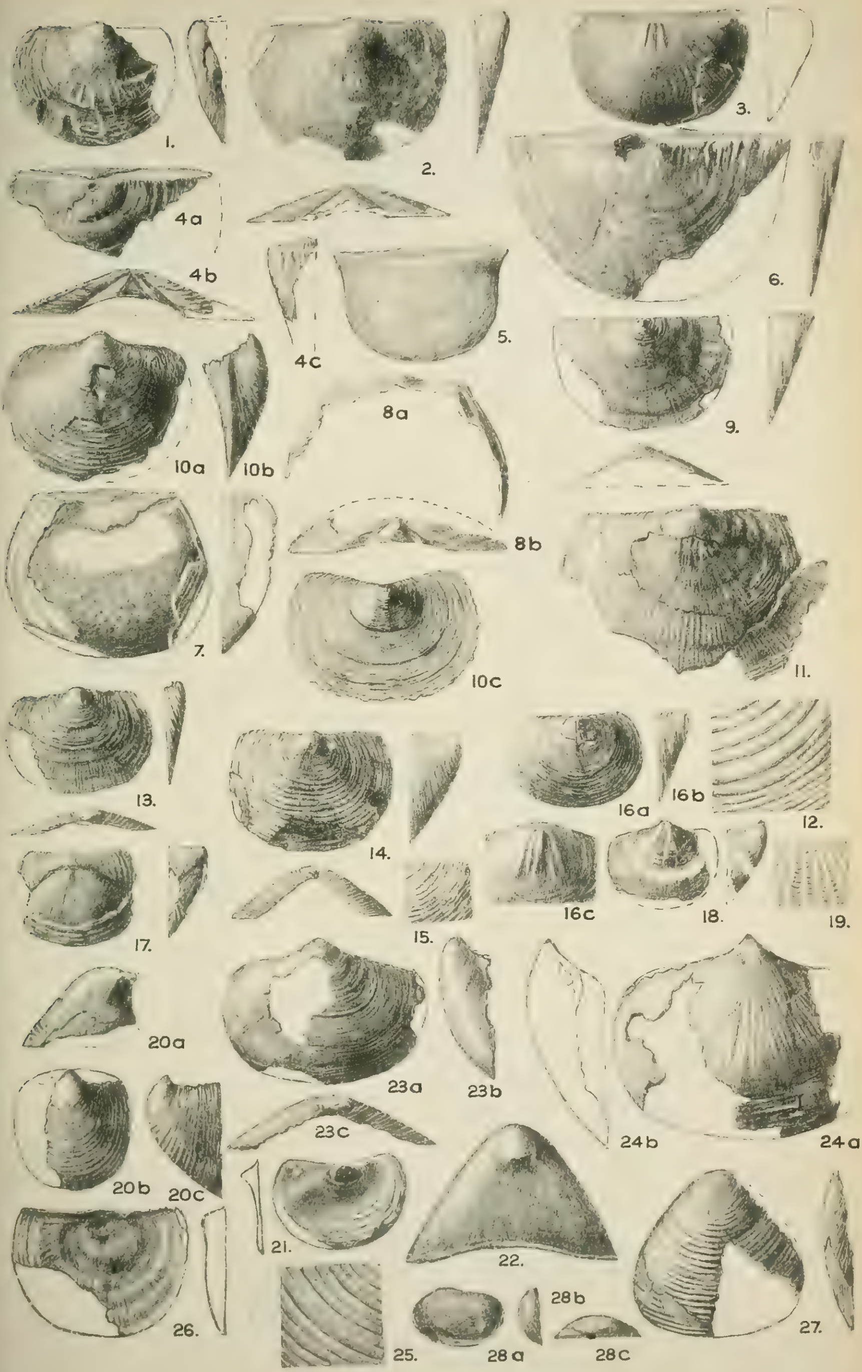
Fig. 10. The two valves in contact; *a*, ventral; *b*, lateral; *c*, dorsal views [British Museum Collection, B. 40306], Ac_2.
11. Dorsal valve, exfoliated, and showing radiate striæ on five successive layers of shell-material [2241], Ac_2.
12. Part of surface of valve in which the rounded concentric bands vary much in width, enlarged to 8 diameters [730], Ac_2.
13. Ventral valve, with lateral and posterior views. The false area is complete, and shows a minute shelf-like pseudodeltidium projecting horizontally under the umbo [2243], Ac_2.

Micromitra (*Paterina*) *minor*, sp. nov., × 8, see p. 333; horizon Ac_2.

Fig. 14. Type-specimen, ventral valve, exterior, with lateral and posterior views [755].
15. Surface of another specimen [RR 1242], × 16.
16. Ventral valve exfoliated at the apex; *a*, summit view; *b*, lateral view; *c*, the exfoliated apex × 16 showing casts of vascular marks and median depression [750].

Micromitra (*Paterina*) *minor*, var. *gibbosa* nov., × 8, see p. 334; horizon Ac_2.

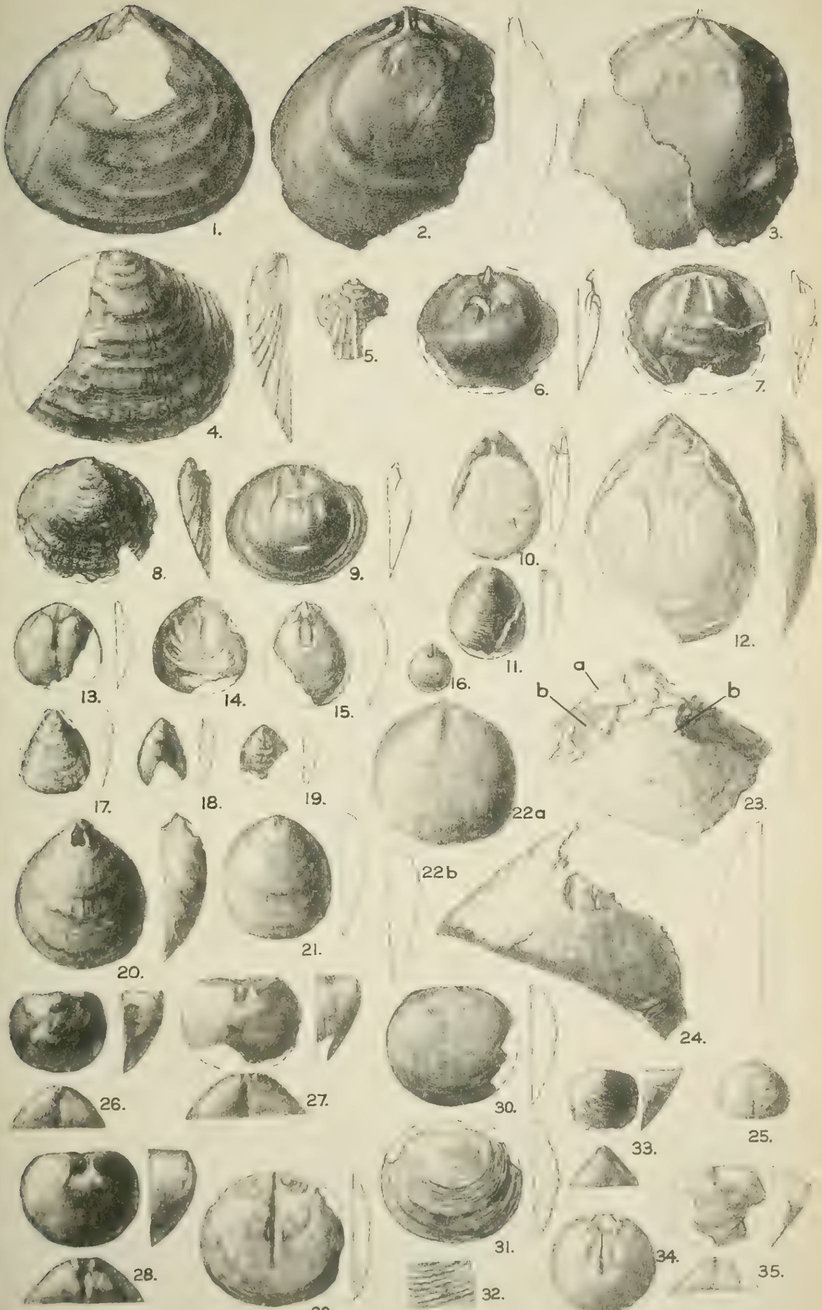
Fig. 17. Ventral valve, summit and lateral views [RR 1117].



E.S.C. del.

Bemrose, Collo., Derby.

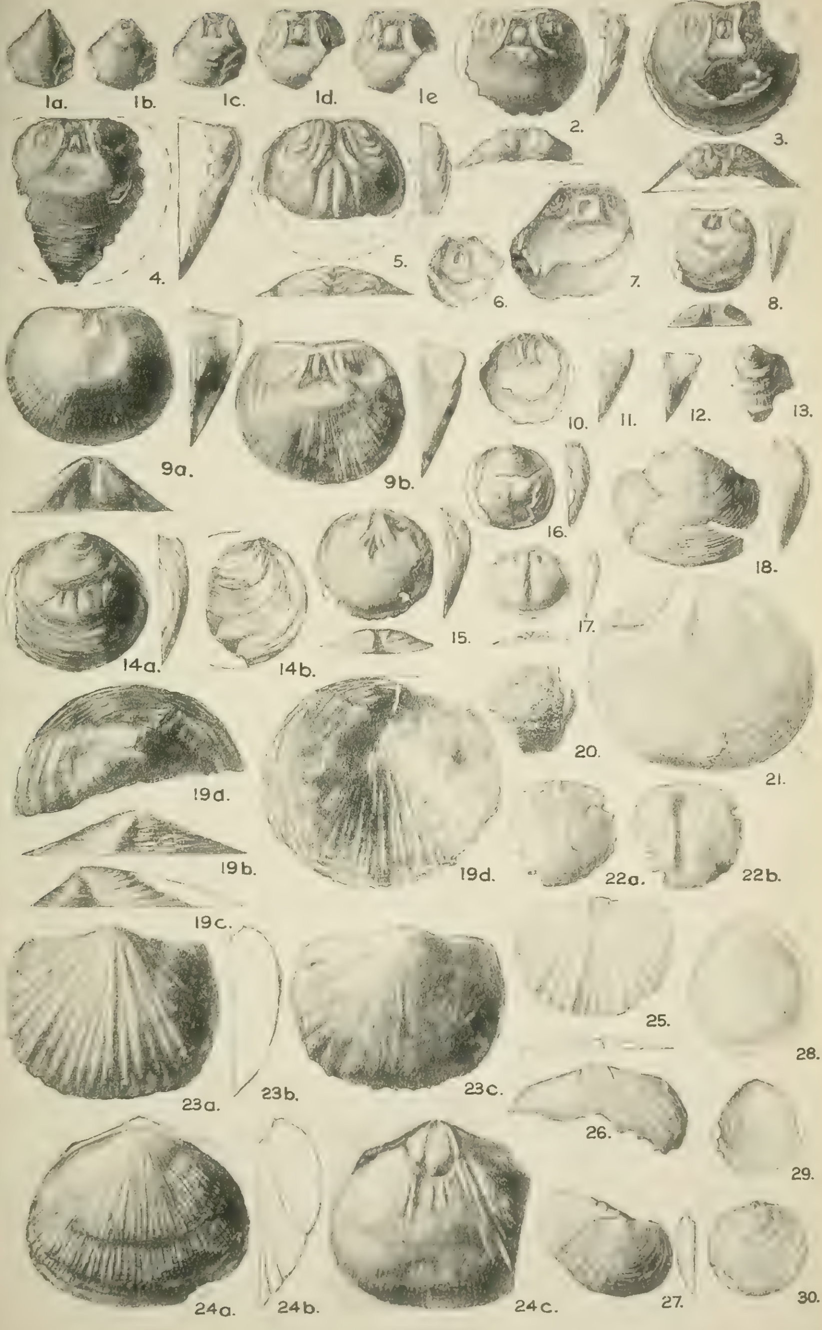
MICROMITRA, WALCOTTINA, OBOLELLA(?), BRADORIA(?) From COMLEY, SHROPSHIRE



E.S.C. del

Bemrose, Collo., Derby.

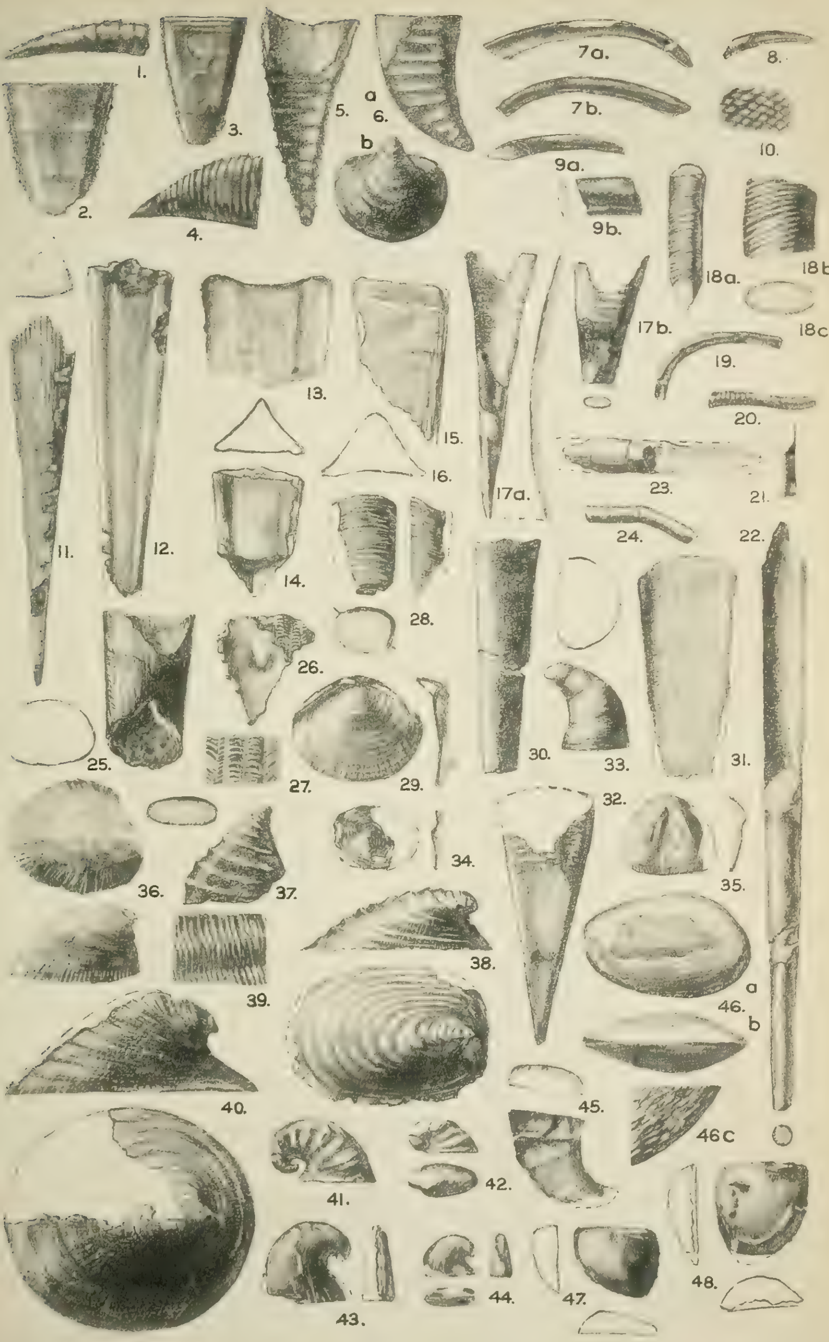
OBOLELLA, LINGULELLA, OBOLUS, ACROTRETA from COMLEY, SHROPSHIRE.



E.S.C. del.

Bemrose, Collo, Derby.

ACROTHYRA, ACROTHELE, BILLINGSELLA, ORUSIA, OBOLUS, ACROTRETA from COMLEY, SHROPSHIR



E.S.C. del.

Bemrose, Collo., Derby.

PTEROPODA, GASTEROPODA & OSTRACODA from the CAMBRIAN of COMLEY, SHROPSHIRE.

Micromitra sp. indet., × 4, see p. 328; horizon Bc.

Fig. 18. Ventral valve, with lateral view [2134].
19. Surface of another specimen [2133] × 8.

Walcottina elevata, gen. et sp. nov., × 4, see p. 337; horizon Ab_1.

Fig. 20. Type-specimen, ventral valve: *a*, internal cast, lateral view [1914]; *b*, exterior, from a squeeze of the external cast; *c*, lateral view of same [1916].
21. Dorsal valve [1916], with lateral view.
22. Ventral valve, posterior view of sandy cast [2282].

Walcottina lapworthi, gen. et sp. nov., × 4, see p. 336; horizon Ab_1.

Fig. 23. Type-specimen, ventral valve, exterior; *a*, summit view; *b*, lateral view; *c*, posterior view [King 1].
24. Ventral valve, exfoliated to the inner layer of shell, with lateral view [King 1].
25. Surface characters, × about 12.

Micromitra (?) sp. indet., × 4, see p. 334; horizon Ab_1.

Fig. 26. Interior, with section in outline [2183].

Obolella (?) groomi Matley, × 5, see p. 345; horizon Ab_1.

Fig. 27. Ventral (?) valve, exterior, with lateral view [2226].

Bradoria (?) sp., × 5, see p. 368; horizon Ac_2.

Fig. 28. Right valve [14536] in the British Museum (Natural History) Collection; *a*, lateral view; *b*, terminal view; *c*, dorsal view.

Plate XXII.

Obolella atlantica Walcott, var. *transversa* nov., × 5, see p. 344; horizon Ac_4.

Fig. 1. Type-specimen, dorsal valve, internal cast [810].
2. Ventral valve, internal cast, with lateral outline [807].
3. Do. do. do. [2162].
4. Dorsal valve, exterior [53].
5. Apex of ventral valve, exterior [2189].

Obolella atlantica Walcott, var. *comleyensis* nov., × 5, see p. 342; horizons Ac_1 to Ac_3.

Fig. 6. Type-specimen, ventral valve, internal cast, with lateral outline [1288], Ac_3.
7. Dorsal valve, internal cast with portion of shell adhering [785]; also lateral outline, Ac_2.
8. Ventral valve, exterior, with lateral view [2159], Ac_2.
9. Do. do. internal cast, with lateral outline [766], Ac_2.

Lingulella viridis, sp. nov., × 6, see p. 341; horizons Ac_4 & Ac_5.

Fig. 10. Ventral valve, internal cast, with lateral outline [35].
11. Dorsal valve, exterior, with lateral outline [1996].
12. Type-specimen, dorsal valve, internal cast, with lateral view [97].

Obolus parvulus, sp. nov., × 6, see p. 338; horizons Ac_2 to Ac_5.

Fig. 13. Type-specimen, dorsal valve, internal cast, with lateral outline [1512], Ac_2.
14. Dorsal valve, interior much exfoliated, showing a median ridge representing the median depression of the exterior [1512], Ac_2.

Fig. 15. Ventral valve, internal cast, with lateral outline [2200], Ac_2.
16. Minute ventral valve, internal cast, young and rather wider proportionally than the adult [2198], Ac_2.
17. Ventral valve, exterior, with lateral outline [760], Ac_2.
18. Do. do. do. do. do. do. [1755], Ac_5.
19. Dorsal valve, exterior, with lateral outline [1756], Ac_5.

Obolus (?) gibbosus, sp. nov., × 6, see p. 339; horizon Bc.

Fig. 20. Type-specimen, ventral valve, exterior, with lateral view [2119].
21. Dorsal valve, internal cast, with lateral outline [2120].

Obolus (?) cf. *schmalenseei* Walcott, × 6, see p. 340; horizon Bc.

Fig. 22. Dorsal valve, internal cast; *a*, summit view; *b*, lateral outline [689].

Obolus (?) linnarssoni, sp. nov., × 4 and × 6, see p. 338; horizon Bc.

Fig. 23. Ventral (?) valve, × 4, variously exfoliated, with lateral outline, showing at *a*, portion of exterior; at *bb*, the two raised bands on an inner layer [RR 1868].
24. Dorsal (?) valve, × 6, much exfoliated [2385].
25. Minute valve, × 6, doubtfully referred to the species [2399].

Acrotreta schmalenseei var. *matleyi*, nov., × 6, see p. 346; horizons Bc & (?) Bb_5.

Fig. 26. Type-specimen, ventral valve, exterior, with lateral and posterior views [2066].
27. Ventral valve, exterior, exfoliated and apex removed, with lateral and posterior views [2076].
28. Ventral valve, internal cast, with lateral and posterior views [2109].
29. Dorsal valve, internal cast, with lateral outline [2079].
30. Do. do. exterior somewhat exfoliated, with lateral outline [2078].
31. Dorsal valve, exterior, wider and with surface more strongly marked, doubtfully referred to the species [2103].
32. Surface of a ventral valve, × 12 [2087].

Acrotreta sp. indet. *a*, × 6, p. 347; horizon Bc.

Fig. 33. Ventral valve, internal cast, with lateral and posterior views [2093].

Acrotreta sp. indet. *c*, × 6, see p. 348; horizon Bb_2.

Fig. 34. Dorsal valve, internal cast [1621].

Acrotreta socialis Seebach, × 6, see p. 347; horizon Ba_3.

Fig. 35. Ventral valve, with lateral and posterior views [1640].

Plate XXIII.

Acrothyra comleyensis, sp. nov., × 6, see p. 348; horizons Bb_1 & Bb_3.

Fig. 1. Five drawings of the apical part of a ventral valve [1714], from which successive layers of shell were removed; *a*, exterior; *b*, first exfoliation, showing, so far as the curved line, the internal cast of a young shell; *c*, second exfoliation, showing internal cast of a small shell attaining adult features; *d* and *e*, further exfoliations, showing further stages of growth.
2. Type-specimen, ventral valve, internal cast [1710], from which all the shell has been removed, with lateral and posterior views.

Fig. 3. Ventral valve, internal cast [1708], with posterior view; some shell remains on the cast.
4. Ventral valve, internal cast [1709], with lateral view; much shell remains on the cast.
5. Dorsal valve, internal cast, with lateral and posterior views [1707].
6. Ventral valve, interior [1711].
7. Do. do. do. [1706], the visceral cavity more rotund than usual.
8. Ventral valve, internal cast, young individual, with lateral and posterior views. The visceral cavity is somewhat rotund [1716].

Acrothyra cf. *sera* (Matthew) Walcott, × 6, see p. 350; horizon Ac.

Fig. 9 *a*. Ventral valve, exfoliated slightly, with lateral and posterior views [1].
9 *b*. The same valve, from which all the shell has been removed, with lateral view.
10. Ventral valve, interior [2218].
11. Do. do. lateral view, posterior slope inclined backwards [1800].
12. Ventral valve, lateral view, posterior slope vertical [1799].
13. Do. do. exterior of apical portion [2207].
14 *a*. Dorsal valve, strongly exfoliated, with lateral outline [2207].
14 *b*. The counterpart, showing many laminæ [2208].
15. Dorsal valve, internal cast, with lateral and posterior views [1801].
16. Smaller dorsal valve, partial exterior, with lateral view [1801].
17. Dorsal valve, internal cast, with lateral and posterior views, showing a greater extension of the median septum [1781].
18. Dorsal valve, exterior, with lateral view, much wider than usual and showing strongly-marked sculpture [18].
[The specimens represented by figs. 17 & 18 are referred doubtfully to the species.]

Acrothele coriacea Linnarsson, × 6, p. 345; horizons Bb_5, Bc, & Ca.

Fig. 19. Ventral valve, partly exfoliated. The surface of the shell is seen near the posterior margin where the sculpture is linear, towards the apex it is granular; *a*, summit; *b*, posterior view; *c*, lateral view [2345].
19 *d*. Exfoliated interior of the same shell [2346].
20. Ventral (?) valve, fragment of external surface [2349].
21. Dorsal valve, exfoliated, but showing two portions of the exterior, with lateral outline [2352].
22 *a*. Dorsal valve, exfoliated, showing one of the two apical tubercles and a slight median depression [2379].
22 *b*. The same specimen, after much shell-substance had been removed.

Billingsella sp. indet., × 3, see p. 354; horizon Bb_1.

Fig. 23. Ventral valve, exterior from a squeeze of the cast; *a*, summit view; *b*, lateral outline [1880].
23 *c*. Internal cast of the same [1879].

Billingsella lindstrœmi, var. *salopiensis* Matley, × 3, see p. 353; horizons Bb_5 & Bc.

Fig. 24. Ventral valve, exterior from a squeeze of the cast; *a*, summit view; *b*, lateral outline [2450], Bc.
24 *c*. Internal cast of the same [2449], Bc.

Orusia lenticularis Wahlenberg, × 4, see p. 354; horizon Ca.

Fig. 25. Dorsal valve, internal cast, with posterior view, showing casts of convergent crural plates [2509].
26. Ventral valve, internal cast, showing casts of divergent dental plates [2507].
27. Ventral valve, exterior, with lateral outline; and dorsal valve, internal cast, showing casts of parallel crural plates [2516].

Obolus sp. indet. *b*, × 6, see p. 340; horizon Bb_2.

Fig. 28. Ventral valve, internal cast [1621].

Obolus sp. indet. *a*, × 6, see p. 340; horizon Ba_2.

Fig. 29. Dorsal (?) valve, external cast [1604].

Acrotreta sp. indet. *b*, see p. 348; horizon Ba_2.

Fig. 30. Ventral valve, crushed exterior [1606].

Plate XXIV.

Lapworthella nigra, gen. et sp. nov., × 10, see p. 360; horizon Ad.

Fig. 1. Exterior of attenuate example, slightly damaged [RR 1221].
2. Internal cast, with shell in section [266].
3. Surface of inner shell, showing (where broken away) a portion of the internal cast [RR 1221].
4. Exterior of wide example, somewhat worn [RR 1221].
5. Interior of outer covering, with portion of inner shell adhering [267].
6. Wide individual, detached from the matrix and somewhat abraded: *a*, summit; *b*, lateral view [270].

Helenia cancellata, sp. nov., × 4, see p. 363; horizons Ac_2 to Ad.

Fig. 7 *a*. Type-specimen, external impression, with closed end preserved [246], Ac 2.
7 *b*. Same individual, showing marginal groove [245], Ac_2.
8. Another closed end [243], Ac_2.
9 *a*. Another specimen × 4 [246], Ac_2.
9 *b*. The same × 10, with section.
10. Diagram, showing character of sculpture.

Hyolithus (*Orthotheca*) *bayonet*, var. *striatus* nov., × 4, see p. 357; horizon Ac_4.

Fig. 11. One of the ventral faces, with section [231].

Hyolithus (*Orthotheca*) *bayonet* Matthew, × 4, see p. 357; horizon Ac_5.

Fig. 12. Dorsal face [2567].
13. Dorsal apertural margin, external cast [2572].
14. Dorsal face, fragment, with section [2568].
15. One of the ventral faces [2576].
16. Section, more in accordance with Dr. Matthew's description than fig. 14 [1672].

Hyolithus (*Orthotheca*) *compressus*, sp. nov., × 4, see p. 357; horizon Ac_2.

Fig. 17. Type-specimen; *a*, part of an external cast, with outline of curvature [225]; *b*, exterior, with section [226].

Salopiella obliqua, gen. et sp. nov., × 4, see p. 363; horizon Ac_5.

Fig. 18. Type-specimen [242]; *a*, internal cast or exterior (?), × 4; *b*, enlargement of surface, × 10; *c*, section, × 10.

Hyolithellus micans Billings, × 4, see p. 361; horizons Ac_1 to Ba_3.

Fig. 19. A curved example [252], Ad.
20. A sinuous example [251], Ad.
21. A straight example [1778], Ad.

Hyolithellus micans, var. *robustus* nov., × 4, see p. 362; horizons Ba_1 to Bb_1.

Fig. 22. A long fragment, with section [1695], Bb 1.

Hyolithellus micans, var *pallidus* nov., × 4, see p. 362; horizons Ab_2 & Ab_3.

Fig. 23. A fragment [1261].

Hyolithellus (?) sinuosus, sp. nov., × 10, see p. 362; horizon A_1.

Fig. 24. Type-specimen [1912].

Hyolithus sculptilis, sp. nov., × 4, see p. 356; horizon Ac_5.

Fig. 25. Type-specimen [2587], with section.
26. Fragment of shell [2585].
27. Character of sculpture [2583], × 6.

Hyolithus crassus, sp. nov., × 2, see p. 354; horizon Ac_5.

Fig. 28. Type-specimen, dorsal face, lateral view and section [2603].

Hyolithus sp. indet., operculum, × 4, see p. 356; horizon Ac_5.

Fig. 29. Complete specimen, with section [2655].

Hyolithus strettonensis, sp. nov., × 2, see p. 355; horizon Ab_1.

Fig. 30. Type-specimen, internal cast, lateral view with section [1903].
31. Dorsal face, external cast [1902].

Hyolithus strettonensis, var. *brevis* nov., × 4, see p. 355; horizon Ab_1.

Fig. 32. Dorsal face [220].

Salterella (?) bella, sp. nov., × 10, see p. 360; horizon Ac_5.

Fig. 33. Type-specimen, lateral view [523].

Hyolithus (*Orthotheca*) sp. indet., operculum, × 4, p. 358; horizon Ac_5.

Fig. 34. Exterior [2655].

Hyolithus (Orthotheca ?) sp. indet., operculum, × 4, see p. 358; horizon Ac_5.

Fig. 35. Internal cast, with section [2656].

Scenella elevata, sp. nov., × 6, see p. 364; horizon Ac_2.

Fig. 36. Type and only specimen, summit and lateral views [RR 1211].

Helcionella cingulata, sp. nov., × 4, p. 364; horizon Ac_5.

Fig. 37. Type-specimen, incomplete, lateral view and section [827], Ac_5.

Helcionella oblonga, sp. nov., × 2, see p. 365; horizon Ba_1.

Fig. 38. Type-specimen, lateral and summit views [1316].
39. Sculpture, × 5 [1314].

Helcionella rugosa Hall, var. *comleyensis* nov., × 4, see p. 365; horizons Ac_1 & Ac_2.

Fig. 40. Type-specimen, lateral and summit views [1897].

Latouchella costata, gen. et sp. nov., see p. 366; horizons Ac_2 & Ac_5.

Fig. 41. Type-specimen [in the collection of the Rev. W. M. D. La Touche]. internal cast, × 5, Ac_2.

42. Second specimen, exterior, lateral & summit views, × 2 [2682], Ac_5.

Latouchella (?) striata, sp. nov., × 2, see p. 367; horizon Ac_5.

Fig. 43. Type-specimen, lateral and terminal views [2655].

44. Another specimen, lateral, summit, and terminal views [2659].

Salterella (?) striata, sp. nov., × 6, p. 361; horizon Ac_5.

Fig. 45. Type-specimen, lateral view and outline of aperture [139].

[By misadventure this figure has been reversed in position, giving the appearance of a concave instead of a convex object.]

Leperditia lentiformis, sp. nov., × 2, see p. 367; horizon Ac_2.

Fig. 46. Type-specimen [51 in the Birmingham Museum], two valves in position; *a*, left side; *b*, dorsal aspect; *c*, surface × 6.

Escasona (?) spp. indet., × 6, see p. 368; horizon Ac_2.

Fig. 47. [RR 1332], with profile outlines.

48. [RR 1335], with do. do.

10. *The* Scandinavian 'Mountain Problem.' By Prof. Olaf Holtedahl, Ph.D. (Communicated by Sir Archibald Geikie, O.M., K.C.B., F.R.S., For.Sec.G.S. Read June 23rd, 1920.)

A general feature in the geological structure of the eastern zone of the Caledonian mountain-range of the Scandinavian Peninsula is the existence of highly metamorphic, often gneissose, unfossiliferous rocks above slightly-altered fossiliferous Cambro-Silurian sediments. This feature is met with from the Stavanger district in the south to Finmarken in the north.

It is now more than thirty years since the Swedish geologist A. E. Törnebohm[1] suggested that this remarkable feature, this 'mountain problem' of Scandinavia, might be explained by employing the overthrust theory: by assuming, as had proved to be the fact in Scotland, that the overlying metamorphic rocks originally belonged to the pre-Cambrian System, and by means of an enormous thrust had been brought into their present position above what was left of the Cambro-Silurian sedimentary series.

After further investigations, *inter alia* in the Norwegian mountain-district of Jotunheimen (see map, fig. 1, p. 388), Törnebohm became increasingly convinced of the correctness of this view, of the ancient date of, for instance, those metamorphic stratified rocks of Central and South-Western Southern Norway for which the Norwegian investigator Th. Kjerulf had established the term 'höifjeldskvarts': that is, 'Highland Quartz' (or Highland Quartzite). In 1896 appeared Törnebohm's famous paper[2] on the geological structure of Central Scandinavia, in which, among others, the well-known sections from the Trondhjem district of Norway in the west, into Jemtland in Sweden in the east, showing an immense overthrust from west to east, were published.

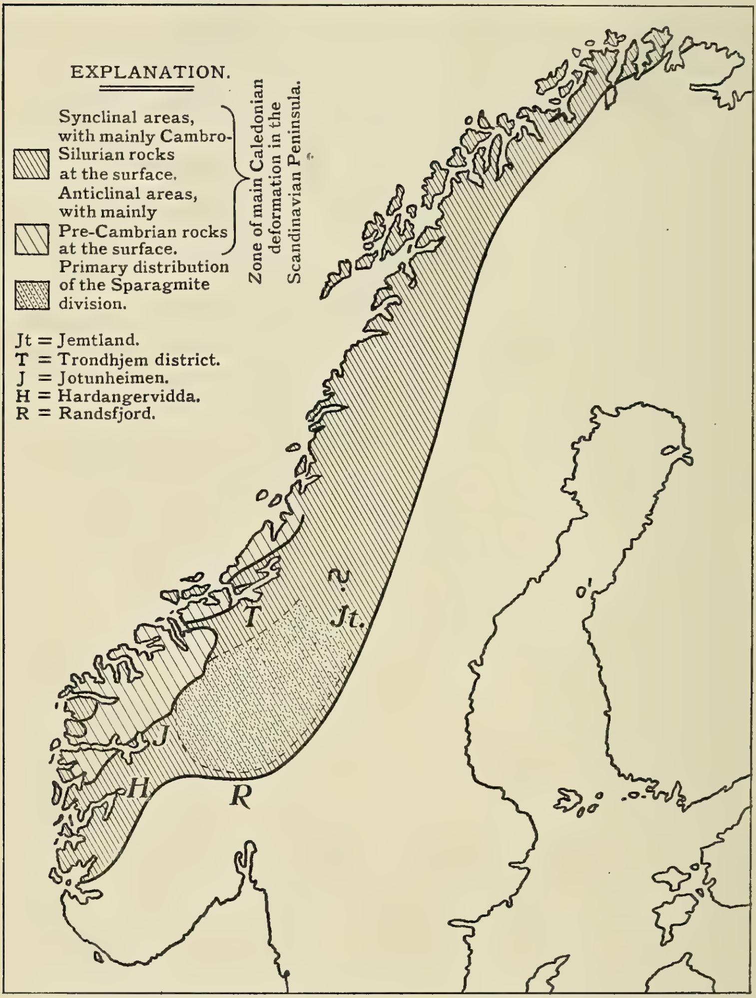
During subsequent years Törnebohm's views were taken up by several other Swedish investigators: thus by A. G. Högbom for the Jemtland district, A. Hamberg for the Sarek district of Northern Sweden, and P. J. Holmquist for the Torneträsk district still farther north. Yet Holmquist did not believe in the very extensive overthrust, but explained the facts by assuming that the roots of the thrust-masses were not very far distant.

When the geologists of various nations met at Stockholm at the International Congress in 1910, the overthrust theory was by far the dominating one in Sweden. It was believed that the metamorphosed rocks of chiefly sedimentary origin—the 'Seve Group' of Törnebohm—lying above the unaltered sedimentary rocks along

[1] Geol. Fören. Stockholm Förhandl. vol. x (1888) p. 334.

[2] 'Grunddragen af det Centrala Skandinaviens Bergbyggnad' Kgl. Svenska Vetensk.-Akad. Handl. vol. xxviii, No. 5.

Fig. 1.—*Sketch-map of the Scandinavian Peninsula, showing the zone of main Caledonian deformation.*



the eastern part of the Scandinavian mountain-belt, were an equivalent of the 'Sparagmite Formation,' a thick series of felspar-bearing sandstones, which in parts of Central Southern Norway lie directly below the *Olenellus* (*Holmia*) Beds, and were regarded as late Pre-Cambrian (Algonkian). It was further held that the igneous masses of the same metamorphic cover (as, for example, the amphibolites, syenites, etc. of northernmost Sweden) were of Archæan age.[1] There was at that time one Swedish geologist only who was in sharp opposition to the theory of the thrust Pre-Cambrian masses, namely, F. Svenonius, who had for a long period made investigations in the mountain-regions, especially of Northern Sweden.

In Norway matters developed otherwise. There the view that the 'Highland Quartz' of Kjerulf, the Norwegian parallel to the Seve Group, was, despite its highly metamorphosed character, geologically younger than the phyllites and shales below, gradually became the predominant hypothesis.

In 1893 W. C. Brögger gave a detailed description of the geology of the district of Hardangervidda[2] (H in the map, fig. 1), where above the Archæan occur phyllites, including alum-shales with *Dictyograptus flabelliformis* at the base. These phyllites pass upwards into highly-metamorphosed stratified rocks (mica-schists, hornblende-schists), sometimes of a typical gneissose character. Brögger came to the conclusion that the latter lay normally on the phyllites, that they consequently represented sediments of later and probably Silurian age. The crystalline character was explained as due to a combined regional and contact-metamorphism which was developed during the time of general deformation under the influence of huge intrusions of igneous masses which had once covered the whole district, and are still preserved in the central zone of deformation, in the coastal districts west and north-west of Hardangervidda.

After 1900 Kaldhol and Rekstad published important papers on the geology of these districts, where they found conditions (intrusive contacts, etc.) that could only be explained by assuming the aforesaid igneous rocks to be younger than the phyllite, intruded into the phyllites during the Caledonian deformation.

This later age of the igneous masses of the South Norwegian mountain-districts was further strongly emphasized by K. O. Björlykke in 1905, in an extensive memoir[3] on the geology of Central Southern Norway. Björlykke had first, after a visit to the North-West Highlands of Scotland, endeavoured, like Törnebohm, to develop the theory of overthrust Archæan masses, but further investigations convinced him that the actual conditions could not be explained in this way. Of great importance for the explanation of

[1] See Törnebohm's article & map in Guide-book No. 1 of the International Geological Congress, XIth Session, Stockholm 1910.

[2] Norges Geologiske Undersökelse, No. 11.

[3] 'Det Centrale Norges Fjeldbygning' Norges Geol. Undersök. No. 39.

the 'mountain problem,' according to Björlykke, is the existence in large areas of Southern Norway of a series of felspar-bearing sandstones, the 'younger Sparagmite of Valdres': these are doubtless younger than the Ordovician phyllites, which they unconformably overlie. Through metamorphism of this Sparagmite have originated rocks like those making up the sedimentary part of the 'Highland Quartz.'

Of Norwegian geologists only one (namely, H. Reusch) had, before 1910, to some extent advocated the view of the Archæan age of the igneous masses in certain districts of the mountain-zone in question.

During the ten years that have elapsed since the Stockholm Congress much work has been done concerning the 'mountain problem,' both in Norway and in Sweden.

For Southern Norway the idea of the later than Pre-Cambrian age of the igneous masses of the mountain-zone has since 1910 been especially emphasized by V. M. Goldschmidt, who has published a series of very important papers on highland geology [1]: on the deformation of the Pre-Cambrian surface, the petrology of the igneous rocks, the metamorphism of the sediments, etc.

In the northernmost part of Norway Th. Vogt and I have made investigations without discovering any facts that indicate a Pre-Cambrian age for the deformed rocks that overlie the unaltered Lower Cambrian sediments (the so-called '*Hyolithus* Zone'), which here, as in Northern Sweden, occur as a narrow belt between the Pre-Cambrian area on the south-east and the metamorphosed masses on the north-west.

In Northern Sweden, in the Ruoutevare district, A. Gavelin [2] found, as a result of detailed study, that the metamorphosed sediments, the 'Seve Group,' probably represent ordinary Cambro-Silurian rocks in a highly-metamorphosed state. As to the igneous masses lying above the '*Hyolithus* Zone' (in this district especially anorthosites and amphibolites) Gavelin came to the conclusion that they were intruded in the Seve rocks during the period of general deformation.

Also P. Quensel [3] has pointed out for a region of Northern Sweden (the Kebnekaise district) that there are strong reasons for assuming that, at any rate, a great part of the Seve Group rocks consists of metamorphosed Cambro-Silurian sediments, and that large masses of the igneous rocks are younger intrusives.

There is no doubt that, at present, the views of the majority of Scandinavian (including the Swedish) geologists, on the 'mountain problem' are vastly different from those expressed in the Swedish guide-books of 1910. While the principle of thrusting, introduced into Scandinavian geology by Törnebohm, is now to a considerable extent accepted, the geological age of the masses moved is, by the

[1] Published in Videnskapsselskapets Skrifter, Kristiania, 1912–16.
[2] Geol. Fören. Stockh. Förhandl. vol. xxxvii (1915) p. 17.
[3] *Ibid.* vol. xli (1919) p. 19.

majority of workers, considered not to be Pre-Cambrian, but later.

As to the igneous rocks of the metamorphic cover, their later (Caledonian) age and intrusive character must now be considered proved in a great many districts. The thrust igneous rocks that must still be regarded as Pre-Cambrian, like the porphyries at the front of the thrust-masses in Jemtland, do not seem to be of more than local importance.

As to the metamorphosed sedimentary rocks lying above the unaltered rocks, the main question has been whether these rocks are to a great extent equivalents of the Sparagmite Division, or whether they are younger. It was stated above that, on Törnebohm's hypothesis, the Sparagmite Formation (which by some has been regarded as a parallel to the Torridonian of Scotland) is referred to the Pre-Cambrian, a fact that made the existence or non-existence of these rocks above the fossiliferous Cambro-Silurian a question of considerable general importance.

Among Norwegian geologists the Sparagmite Formation, or the Sparagmite Division, as it may perhaps better be termed, has not generally been regarded as a true Pre-Cambrian series. In Kjerulf's stratigraphical system the division was classified together with the fossiliferous Cambro-Silurian rocks, as a basal series (stage 1*a*), and Brögger has regarded the Sparagmites as a basal Cambrian division ('Eocambrian'). Recently J. Kiær has emphasized[1] that the division should naturally be placed in the true Lower Cambrian. Seen in this light, the question of the occurrence of the Sparagmite Division in the thrust-complex has no such primary importance, as in general the true Pre-Cambrian has not been thrust. We are, in any case, dealing with rocks which originally belong to horizons above the Pre-Cambrian surface.

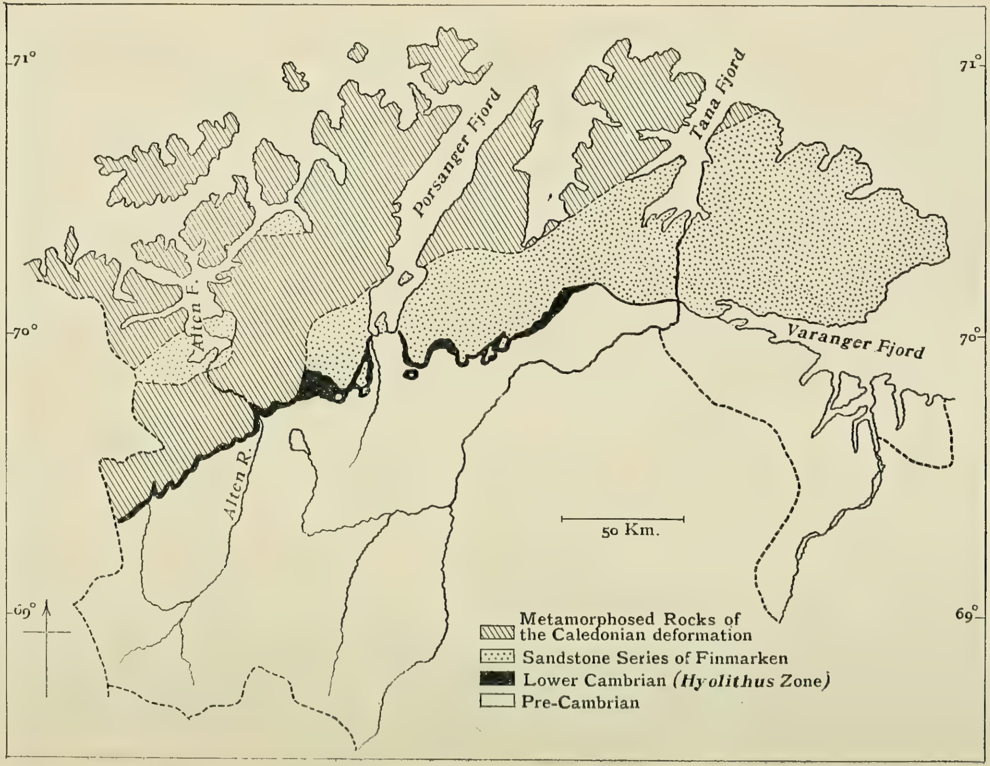
Yet the Sparagmite Division, with its huge thickness, several thousand feet, of coarse clastic rocks, is a stratigraphical element of singular importance, and the question of the part which this element plays in Scandinavian mountain geology is therefore naturally one of very great interest. While it must now be considered proved that Törnebohm's Seve Group in many districts is no equivalent of the Sparagmite Series, but of later Cambro-Silurian age, yet it is beyond doubt, as will be stated further below, that in places in Southern Norway the thrust-masses to a large extent primarily belong to the Sparagmite Division, and thus are older than the oldest-known fossiliferous Cambrian sediments in the same districts.

It being thus evident that in different areas different stratigraphical members make up the thrust-masses, what is the reason for this? Does there seem to be any general rule as to the constituents of the thrust-complex in different districts?

The question may be answered thus: In the thrust-masses

[1] 'The Lower Cambrian *Holmia* Fauna at Tömten in Norway' Vidensk. Skrift. Kristiania, 1916.

Fig. 2.—*Main geological features of Finmarken in Northern Norway.*



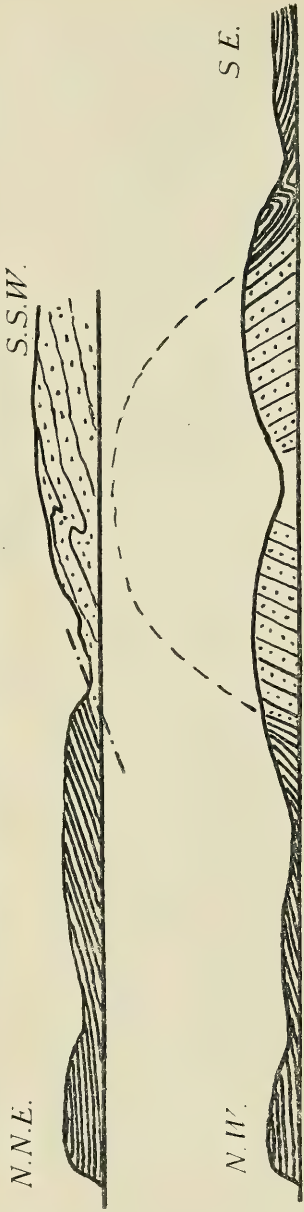
very often, not only one, but several stratigraphical divisions of the Cambro-Silurian formations are present. The age of the thrust sedimentary masses depends on the inclination of the thrust-planes and on the depth which their proximal part has reached. As these planes seem to have reached very far down towards, but generally not below, the Pre-Cambrian surface, the existence or non-existence of thrust-rocks of Sparagmite age may be held to depend upon the primary occurrence or non-occurrence of the Sparagmite Division north-west of the areas where the thrust-masses now occur.

In order to illustrate this statement, we may briefly consider the tectonic features of two widely-separated Norwegian areas where I have made personal investigations.

The first is Finmarken, the northernmost district of Norway. There, in a north-western belt, occur the metamorphic rocks of the mountain-zone, as will be seen from the map (fig. 2, p. 392). In this belt large igneous masses (granites, gabbros, etc.) occur, especially in the north-west, that is, in the central belt of deformation, where the Pre-Cambrian surface must be situated at a very considerable depth. Th. Vogt found these rocks there to be younger intrusive masses, intruded into the mica-schists, quartzites, etc. Also in the south-eastern part of the metamorphic zone corresponding igneous rocks are found, mostly much crushed, often gneissose, granites, also gabbros, here making up a distinct horizon in the huge cover of stratified rocks, which in the far south-east is seen to overlie the unaltered Lower Cambrian shale-sandstone series, the '*Hyolithus* Zone.' The base of this metamorphic cover generally represents a typical thrust-plane, which is seen to have a rather undulating character. This undulation of the bordering plane between metamorphic and non-metamorphic rocks is illustrated in the sections (fig. 4, p. 396), and is also evident from a study of the map (fig. 2). While in the western part of Finmarken only 450 to 500 feet of unaltered sediment come in between the sub-Cambrian peneplane and the metamorphic cover, we find farther north-east, as in the Porsanger Fjord, below this cover about 1500 feet of somewhat folded sandstones, with at the top a thick dolomite-layer. This is what I have called the Porsanger Series (Porsanger Sandstone & Porsanger Dolomite). South and south-east of the above-mentioned fjord this Porsanger Sandstone is seen to overlie, doubtless normally, the Lower Cambrian. At the Alten Fjord appears, in a 'window' in the metamorphic cover, the Raipas Series (sandstone, brownish-weathering dolomite, shale, and greenstone), which must be considered of still later age than the Porsanger Series, all these sedimentary divisions being in my opinion of early Ordovician age and belonging to a huge American-Arctic basin of deposition (as I have stated elsewhere).[1]

[1] See 'Bidrag til Finmarkens Geologi' Norges Geol. Undersök. No. 84, 1918; 'On the Palæozoic Formations of Finmarken in Northern Norway' Amer. Journ. Sci. ser. 4, vol. xlvii (1919) p. 86; and 'On the Palæozoic Series of Bear Island, &c.' Norsk Geol. Tidsskrift, vol. v (1919) p. 141.

Fig. 3.—*Diagrammatic sections in the north-western part of the Varanger Peninsula, both starting (on the left) at the north-westernmost corner of the peninsula.*



[The upper section is taken at the Tana Fjord, the lower on the northern coast.]

Before describing the typical section from the Alten district I may briefly refer to the features met with in the north-eastern part of Finmarken, in the easternmost area of metamorphic rocks in the Scandinavian mountain-range. There, on the eastern side of the Tana Fjord, are seen to the south folded compact sandstones (as illustrated in fig. 3), while farther north occur sedimentary rocks of quite another character, highly-schistose quartzites together with phyllites, having a regular slight north-westerly dip, as is usual in the metamorphic complex. The metamorphic and non-metamorphic series are here found close one to the other, and a thrust-plane must doubtless be assumed. On the northern coast, east of the Tana Fjord, conditions are different. There the phyllite-quartzite series gradually passes into the compact sandstone just mentioned, and still farther east this sandstone is normally overlain by a complex which no doubt corresponds with that seen at the mouth of the Tana Fjord, but, being situated outside the zone of strongest pressure, shows much less deformation. Thus the metamorphic series to the north-west in this area is, generally speaking, of the same age as the non-

metamorphic series south-east of the bordering line of the thrust-masses. Compared with Western Finmarken, this quartzite-phyllite (or on the south-east, sandstone-shale) horizon seems to correspond with the lower part of the Raipas Series, just mentioned.

As to the section in the Alten district (see fig. 4, p. 396) we find here, above the thrust-plane (marked with vertical striation in the drawings), much-deformed, generally somewhat crystalline stratified rocks that represent felspar-bearing sandstones, and further phyllites, quartzitic bands, and dolomites. It is especially these dolomites that, in my opinion, make it possible to draw conclusions as to the relative age of the thrust-masses and the general tectonic features.

At the south-eastern border of the thrust-complex is observed, at the base of the deformed sandstones, a small irregular mass of grey dolomite with a peculiar oolitic structure, a rock which undoubtedly must belong to the Porsanger Dolomite horizon.

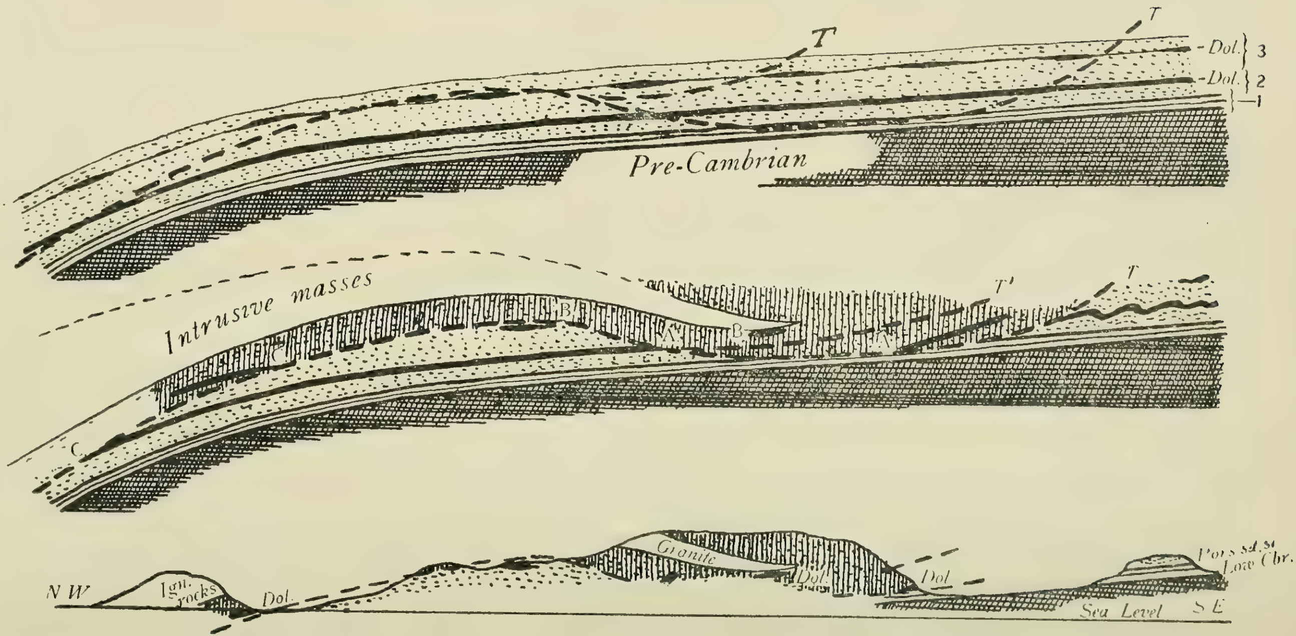
A very coarse-grained dolomite is found in connexion with the igneous rocks midway between this locality and the Alten Fjord. This rock, with its brownish weathering (the Porsanger Dolomite weathers greyish-white), may naturally be regarded as a mass of Raipas Dolomite which has been moved south-eastwards.

On the north-west, at the Alten Fjord, occur in the basal part of the thrust-complex layers of dolomites of highly-varying thickness. On the eastern side of the fjord the lower dolomite-layer is situated a little way up from the base of the metamorphic complex, while on the west the dolomite makes up the very base. The dip is towards the north-west. The rocks above are much-deformed felspar-bearing sandstones, the true character of which, however, is increasingly difficult to identify as we pass towards the north-west: the rocks become gradually more metamorphic and crystalline. We soon find rocks of distinct gneissose character, and still farther north-west we meet with true igneous masses, partly of more acid, partly of gabbroid character, rocks that, as mentioned above, show distinct intrusive characters. The lower, in places non-crystalline, yet much deformed and jointed, dolomitic layer just mentioned, is of peculiar interest, because it is so very like the Porsanger Dolomite that its attribution to that horizon cannot be gainsaid.

It thus seems, from studies in Western Finmarken also, that at any rate the greater part of the metamorphic sedimentary rocks lying above the non-metamorphic must be regarded as being, generally speaking, of the same age as the unaltered rocks occurring below the thrust-plane and south-east of the metamorphic zone. They represent the same dolomite-bearing sandstone series in a more or less metamorphosed state.

In fig. 4 (p. 396) is given a somewhat simplified section from west to east through the Alten district, in the south-eastern part, passing the southern outlier of Porsanger Sandstone south-south-west of

Fig. 4.—*Diagrammatic sections illustrating the geological structure of the Alten district.*



the Porsanger Fjord, and also two sections illustrating how, in my opinion, the present structure may be thought to have developed. The original sequence is, according to what has been stated above:—Pre-Cambrian, followed by the Lower Cambrian shale-sandstone series (1), the Porsanger Series (2), with Porsanger Dolomite on the top, then the Raipas Series, etc. (3). The last-named has in pre-Caledonian time been strongly denuded locally, and the Raipas Dolomite is thus only locally preserved. In (3) is included the relatively thin Bossekop Series (sandstones with shales, and at one horizon a tillite).

The main tectonic feature is a major thrust-plane, T, and other minor thrust-planes, T′. In the drawing there is—for the sake of simplification—indicated only one minor thrust-plane. In fact, because of the enormous general pressure, it is very difficult to identify the thrust-planes in the metamorphic complex itself, but from the arrangement of the rocks we may conclude that they must be present. At the south-eastern border of the metamorphic mass, where the pressure has been somewhat less than in the more central zone of deformation, the existence of thrust-planes of secondary order can, however, be distinctly seen. By the letters AA, BB, CC is indicated in the figure the probable movement of the dolomite masses found in the thrust-complex, according to my view. The igneous horizon, the 'intrusive masses' of the figure, does not show a sharp bordering line against the surrounding rocks, which are of the same general character above and below: in fact, there is a bordering zone with gneissose rocks, the original character of which, whether derived from the granites of the intrusion or from the felspar-bearing sandstones, is generally difficult to decide. This apparent gradual transition from igneous to sedimentary rock in the metamorphic complex, without any distinct thrust-plane here, is natural, if we assume an intrusion causing a metamorphism of the surrounding rock, but very difficult to understand if we should assume the igneous mass to be an overthrust Archæan one.

It is evident, from a study of the Alten section with its strongly undulating thrust-plane, that in detail the relation of age between the underlying, relatively unaltered, rocks and the metamorphic sedimentary rocks above, must be very different at various places. It depends upon the inclination of the thrust-plane. At the eastern border of the Scandinavian mountain-belt, from the Alten district and far south into Northern Sweden, the majority of the thrust-rocks must be considered as of a somewhat later age than the unmetamorphic below, as the latter here consist only of the Lower Cambrian division (the *Hyolithus* Zone).

Where, as for example, farther east in Finmarken, and in Jemtland in Central Sweden, the major-thrust-plane occurs much higher up in the Cambro-Silurian Series, thus corresponding to the conditions seen more to the left in fig. 4, we may expect true overthrusts, with older rocks above younger.

In Jemtland we find in places metamorphosed sedimentary rocks lying above so late a zone as the Silurian *Pentamerus* Limestone. Even if the greater part of the metamorphosed rocks of this region is not of the age of the Sparagmite Division, as Törnebohm assumed, but younger, they may well be considered to be older than the above-mentioned Silurian horizon. Probably, as has recently been held by the Norwegian geologist C. W. Carstens,[1] who has made extensive studies in the Trondhjem district, much of the 'Seve Group' in the Trondhjem-Jemtland region is of Ordovician age.

In fact, it seems to be increasingly evident that the metamorphic sedimentary rocks of the central and northern part of the mountain-belt of Scandinavia are chiefly of Ordovician age. The remarkable likeness between the 'mica-schist–marble group,' making up the sedimentary portion of the solid rock-formations of the western part of Northern Scandinavia, and the 'Heclahook System' of Spitsbergen, which system must now be considered to cover early and middle Ordovician time,[2] is in this connexion a point of fundamental importance. Just as more and more of the gneiss and granite-masses of Northern Norway during later years have proved to be Caledonian intrusive and not Archæan rocks, the huge mass of gneiss and granite making up the north-western corner of Western Spitsbergen, and previously regarded as Archæan, is now known to represent intrusions of igneous masses during the Caledonian deformation.[3]

In the map of the Scandinavian Peninsula published in Törnebohm's previously-mentioned Guide-Book (No. 1) of the Stockholm International Geological Congress, the greater part of Northern Norway was mapped as Algonkian Seve rocks, and Archæan granites.

Only for a single, yet far from unimportant, part of the Scandinavian region of strong deformation the actual conditions seem to show that the thrust-masses consist mainly of rocks belonging to the Sparagmite Division, and thus are older than the fossiliferous Lower Cambrian. This is the case along the southern, possibly also parts of the eastern, border of the Sparagmite region of Central Southern Scandinavia (see fig. 1, p. 388), the region where the true Sparagmite Division primarily existed, the exact northern border of which, however, is unknown to us. The fact is that some of the 'Sparagmites' (of, for example, Jemtland) probably represent rocks that are younger than the Lower Cambrian, and therefore do not belong to what should be called the 'Sparagmite Division.' This later age of certain widespread Swedish Sparagmites and quartzites has recently been advocated by G. Frödin.[4]

[1] 'Oversigt over Trondhjemsfeltets Bergbygning' Kgl. Norsk. Vidensk. Skrift. 1919, No. 1.

[2] O. Holtedahl, 'On the Palæozoic Series of Bear Island, &c.' Norsk Geol. Tidsskrift, vol. v (1919) pp. 138–41.

[3] O. Holtedahl, 'New Features in the Geology of North-Western Spitsbergen' Amer. Journ. Sci. ser. 4, vol. xxxvii (1914) p. 415.

[4] Sveriges Geol. Undersökn. ser. C, No. 299, 1920.

To illustrate the conditions in the southern part of the Sparagmite area (a district situated outside the typical overthrust regions of Törnebohm) I have drawn the sections shown in fig. 5 (p. 400), reaching from the Randsfjord (see R in fig. 1) and northwards for a distance of about 60 kilometres (say, 37 miles).

Primarily there occurred in the northern part of this district, at a time immediately preceding the deposition of the Lower Cambrian *Holmia* (*Olenellus*) Shale (which, according to our present knowledge of the Cambrian System of the Cordilleran region of North America, took place some way up in what is now known to be the Cambrian Period), a sedimentation of sandstones (Sp. in the upper section), while on the south some denudation must still have taken place. Moreover, the *Holmia* Shale was deposited only in the north. After a thick series of younger, fossiliferous Cambro-Silurian (C–S) had been deposited throughout the whole region, an inclination of the pre-Cambrian floor took place in late Silurian time. Through pressure from the north thrusting began, and originated a typical imbricate structure as shown in the three lower drawings, the lowest of which represents the actual conditions as now observed. We note thick masses of highly-deformed sandstone (mostly quartzite) above the basal remnants of the fossiliferous Cambro-Silurian Series. These remnants mainly consist of highly-fractured Middle Cambrian alum-shales in which are found species of *Agnostus*, *Paradoxides*, etc.[1] Passing northwards, we observe above the quartzites the grey-green *Holmia* Shale, overlain in turn by the Middle and Upper Cambrian alum-shales, and finally by Ordovician strata.

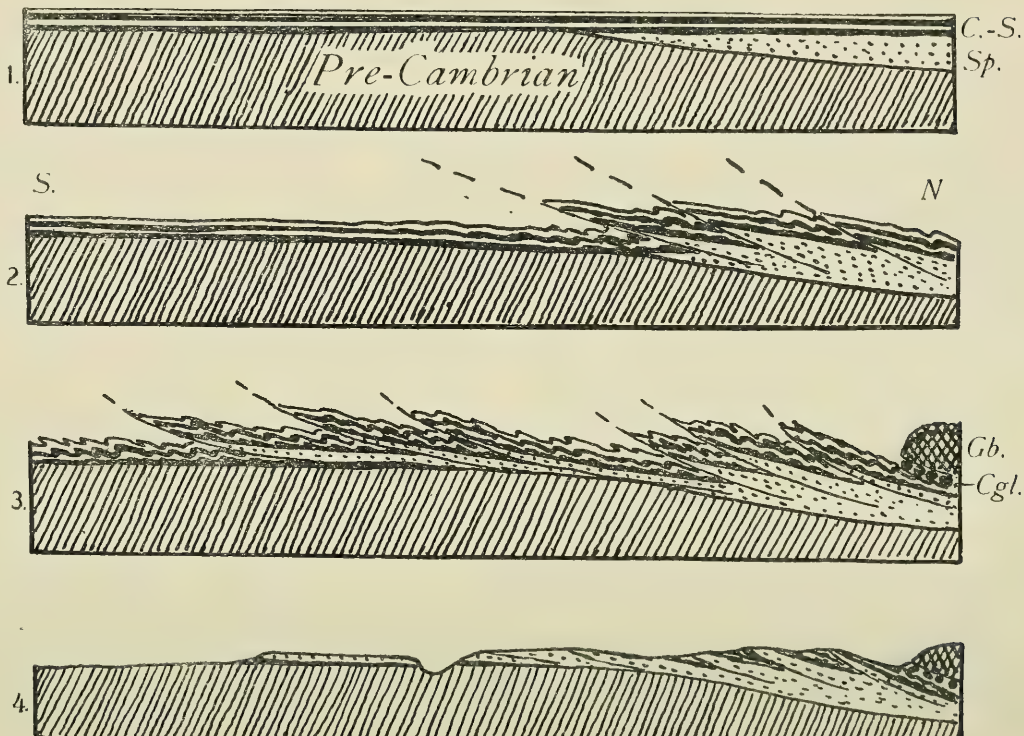
Conditions similar to those observed by me in the Randsfjord district were previously described from a more easterly district of the Sparagmite area in Norway by O. E. Schiötz.[2]

As has already been mentioned, in Southern Norway, for instance, in the eastern part of the Jotunheimen district, a younger, post-Cambrian 'Sparagmite' series exists, which unconformably overlies Ordovician phyllites. This series commonly contains conglomerates, which have recently been studied by V. M. Goldschmidt,[3] who has found much of interest concerning them. In one district the material in the boulders consists to a great extent of a gabbro of the same kind as that seen in a gabbro-mass that overlies the conglomerate. According to Goldschmidt, the material of the conglomerate was originally derived from this gabbro-mass deposited on the south side of it; then, through pressure from the north, the (rest of the) gabbro was thrust over the conglomerate, and covered it. The present conditions are illustrated in the two lower sections in fig. 5, p. 400 (Gb=gabbro, Cgl=conglomerate). In another district a quartz-conglomerate occurs in a similar relation to a mass of granite.

It is evident that, from this point of view, the above-mentioned

[1] Norges Geol. Undersök. No. 75, 1915.
[2] *Ibid.* No. 35, 1903.
[3] *Ibid.* No. 77, 1916.

Fig. 5.—*Diagrammatic sections illustrating the structure of the southern part of the Sparagmite area, from the Randsfjord* (R *in fig.* 1) *and northwards* (*see p.* 399).



gabbro and the granite at the time when the conglomerates were formed, were cooled, solid masses, exposed at the surface. There are also other features generally met with in different districts of the eastern zone of deformation, which indicate that the igneous masses were to a considerable extent moved as solid masses. So we may find very commonly, at the base of the thrust igneous masses, mylonitic zones implying a dynamical crushing of solid material. This might by some perhaps be taken as a proof that the igneous rocks in question, despite other facts, must be considered as of ancient, probably Archæan, age, and not as Caledonian intrusions; but this is certainly not the case.

There is no doubt whatever that the crust-movements which we call 'the Caledonian deformation' have lasted for a very long time. As to this question, I might refer to my recent paper on 'Palæogeography & Diastrophism in the Atlantic-Arctic Region during Palæozoic Time.'[1] It is, further, only natural to assume that the time during which the igneous masses moved or were moved, under constant pressure, from the central zone of deformation to the border-belt 30 to 40 miles away to the south-east, may have been of considerable length.

We do not, therefore, strain our imagination in assuming that more or less of the sheet-like peripheral part of the igneous body was present as a cooled and solid mass, while in the central synclinal zone of deformation, where the roots of the body have to be sought, magmatic masses still poured forth. As to the relation between the conglomerates of the post-Ordovician Sparagmite Series just mentioned and the overlying gabbro and granite, it is evident, if we assume a considerable lapse of time for the deformation, that an igneous mass, the intrusion of which took place in the earlier part of the period of crust-movement, may very well have been exposed and weathered into conglomeratic material before the deformation, the last effort of which was the thrusting of the gabbro and granite above the conglomerates, was finally at an end. This more or less 'dead' state of the igneous masses when they reached far towards the south-east in many cases explains the fact that veins and dykes cutting the underlying sediments are missing here (while they are found in the more central zone of deformation), a fact previously considered as excluding the hypothesis of the later, Caledonian origin of the granites and gneisses.

An important theoretical question to be taken into consideration by future research is the possibility of the intrusions being more or less a *cause* of the movement of the bordering sedimentary masses. It seems probable enough that an igneous body, through a combined regional and contact-metamorphism, might physically become very closely attached to the surrounding mass. As has been stated, we find commonly, as in Finmarken, a wholly crystalline contact-zone. When the igneous mass became consolidated and, through the pressure from magmatic masses, still coming forth from the central

[1] Amer. Journ. Sci. ser. 4, vol. xlix (1920), especially pp. 9–10.

part of the zone of deformation, was pushed towards the south-east and thus a thrust-plane had to be developed, this plane might in some cases be developed far below the igneous body, in the less altered sediments, and the whole overlying mass moved as a unit (compare fig. 4, p. 396).

The future study of the detailed mechanics of the igneous masses in the eastern part of the Scandinavian mountain-zone, these masses being considered not as Archæan tracts of rock, but as parts of Caledonian magmatic bodies, will certainly be one of considerable general interest.

Discussion.

Sir Jethro Teall said that the paper was of great interest to him. It had been his good fortune to be associated with the work of the late Prof. Lapworth in the North-West of Scotland in 1883, and afterwards with that of the Geological Survey. It was obvious that there were resemblances and differences between the two regions. Both Lapworth and the Survey had proved that in certain places undoubted Archæan rocks had been superposed on fossiliferous Lower Palæozoic rocks by powerful earth-movements; but the question of the age and date of the metamorphism of the crystalline schists of sedimentary origin, which occupied the same position in other parts of the North-West, had not as yet been definitely settled, although there was evidence pointing to the conclusion that the metamorphism at least was of post-Cambrian date. Certain igneous rocks of peculiar composition resembling rocks that had been intruded into Cambrian strata—the Canisp porphyrite, for example—had been incorporated as part and parcel of the Moine Schist Series.

The Author maintained that certain crystalline schists overlying the thrusts in Scandinavia were of post-Cambrian age. He (the speaker) would welcome such a conclusion, but would like to study the paper very carefully before expressing an opinion on this point. If clearly established, it would have an important bearing on Scottish geology. He had a perfectly open mind as to the age of the metamorphosed sediments and associated igneous rocks, also metamorphosed, which occupied so large a part of the Scottish Highlands.

Mr. Bernard Smith commented upon the Author's statement that the movements giving rise to thrusts had been from the north and the north-west. In studying phenomena related to Caledonian and later movements in North Wales, the speaker and his colleague (Mr. C. B. Wedd) had been driven to the conclusion that certain structures apparently caused by movements from a northerly or north-westerly direction were really due to deep-seated movements of underlying rocks in the opposite direction. The deep-seated more rigid rocks had moved forward relatively first, while the younger less rigid rock had lagged behind.

He enquired whether it could be shown that the apparent movements from the north and the west, producing the thrusts in Scandinavia, were consequent upon an under-drive of the pre-Cambrian rocks towards the sea, inducing a lagging and piling-up of the overlying Cambro-Silurian strata.

Mr. E. D. Nicholson remarked that it had been stated by some writers, more especially the late James Geikie, that the amount of thrust in the Scandinavian ranges is from 70 to 80 miles. He asked what was the Author's opinion as to the extent of the thrust.

Mr. H. W. Monckton expressed his great interest in the paper. He had for many years followed the development of the mountain problem in Scandinavia, more especially with regard to the Author's southern district, with which he was personally acquainted. There was a double question as to the peculiar gneiss-like masses which form some of the highest ground—whether their position was due to overthrusts, and what was their original geological age? For some time it was believed that they had been derived from the Archæan; but the Author, while adopting the theory of overthrust, considered the overthrust masses to be newer than the Archæan. The speaker thought that the Author had probably arrived at the true solution.

The Author strongly emphasized that it was not possible, in a short paper, to go into detail as to all the facts pointing to a younger age of the metamorphosed sedimentary rocks in the various districts that had now been studied. In addition to what was stated in the paper, he would point out that in the Jotunheimen district metamorphosed sedimentary beds lying above less altered ones quite certainly were equivalents of what is called the 'Younger Sparagmite of Valdres,' which was of post-Ordovician but pre-Devonian age. As to the amount of movement, that of the sedimentary masses was probably not, in his opinion, in the southern part of the 'Sparagmite area' (for example) more than 10 to 20 miles; while the movement of the igneous rocks in the mountain-zone commonly might be much greater, corresponding to the distance between the eastern border of the igneous masses of the metamorphic cover and the central zone of deformation where the masses had poured forth.

GENERAL INDEX

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END OF VOL. LXXVI.

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SESSION 1920–1921.

	1920.	
Wednesday,	November	3*—17*
,,	December	1 —15*
	1921.	
,,	January	5*—19*
,,	February (*Anniversary Meeting*, Friday, February 18th)	2*—23*
,,	March	9 —23*
,,	April	20*
,,	May	4 —25*
,,	June	8 —22*

[*Business will commence at 5.30 p.m. precisely.*]

The asterisks denote the dates on which the Council will meet.

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OF

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Every Candidate for admission as a Fellow must be proposed by three or more Fellows, who must sign a Certificate in his favour. The Proposer whose name stands first upon the Certificate must have a personal knowledge of the Candidate.

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The Fellows are entitled to purchase all publications of the Society at a substantial reduction on the price charged to the general public. Certain of these publications are distributed gratuitously, as issued by the Society.

The Library is open on Week Days to the Fellows between the hours of 10 and 5 (except on Saturdays, when the hours are from 10 to 1, and except during the fortnight commencing on the first Monday in September, see also next page). Under certain restrictions, Fellows are allowed to borrow books from the Library.

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PAPERS READ.

[The Editor of the Quarterly Journal is directed to make it known to the Public that the Authors alone are responsible for the facts and opinions contained in their respective Papers.]

*** The Council request that all communications intended for publication by the Society shall be clearly and legibly written on one side of the paper only, with proper references, and in all respects in fit condition for being at once placed in the Printer's hands. Unless this is done, it will be in the discretion of the Officers to return the communication to the Author for revision.

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Fellows are reminded that, the publication of Vol. LXXVI (1920) being now completed, they will not be entitled to receive the Quarterly Journal regularly, unless a subscription at the rate of 10*s*. per volume is paid in advance, along with their Annual Contribution to the Society. Those Fellows who do not require the complete series can obtain separate parts at the price of 3*s*. each, if applied for within one year of the date of issue.